Final Report

Caltrans

Drain Inlet Cleaning Efficacy Study

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Introduction

1.1 Report Objective

The objective of this Drain Inlet Cleaning Efficacy (DICE) Final Report is to evaluate the California Department of Transportation (Caltrans) drain inlet cleaning program and utilize this information to help Caltrans formulate a long-term program.

The following is a brief summary of the studies and program to be evaluated in this report.

1.1.1 Drain Inlet Cleaning Efficacy (DICE) Study

The DICE Study was initiated by Caltrans in 1996 to evaluate the efficacy of the District 7 cleaning program. This multi-year monitoring study was conducted between the years 1996-1997, 1997-1998, 1998-1999, and 1999-2000 to evaluate the water quality impacts of drain inlet cleaning. In 2000-2001, a litter monitoring element was added to the water quality monitoring. This report is the first comprehensive summary of the program.

1.1.2 Solids Transport and Deposition Study (STDS)

Caltrans conducted the STDS during the period of March 1998 - March 1999. The objectives of the STDS were to characterize the rates and patterns of solids material transfer to, and accumulation in, the storm drain inlets, and to determine what site factors (e.g. roadway configuration, vegetation, surrounding land use, highway litter levels), if any, might affect the transport to and deposition of material in the drain inlets. If clear factors influencing deposition of solids were identified, a focused strategy could potentially be developed to reduce the overall cost of conducting drain inlet cleaning. The results of the STDS were previously published in a Final Report in June 1999 and further evaluated in a STDS Addendum in spring of 2000.

1.1.3 Drain Inlet and Inspection and Cleaning Program (DIIC)

Each year since 1996, Caltrans has conducted a drain inlet inspection and cleaning program in District 7. An extensive database has been compiled under this program, and reports on the program are published annually following completion of each year’s cleaning. The most recent report available during the preparation of this report was from March 2002, following the 2001 inspection and cleaning program.

1.2 Background

Caltrans plans, designs, constructs and maintains large-scale transportation facilities. Caltrans also has the responsibility of accomplishing its missions in ways that comply with public policy and applicable regulations. To protect public safety and prevent property damage, Caltrans operates its storm water drainage systems to minimize flooding and prevent the presence of standing water on traveled surfaces. Runoff is typically directed off roadway surfaces (and other paved areas and non-paved areas within a right-of-way) via drainage systems within or adjacent to Caltrans rights-of-way. Some drainage systems discharge directly to receiving waters; others discharge to municipal storm drain systems. Highways in urban settings typically have curbs and gutters, whereas freeways and rural highways typically have off-shoulder or median drainage swales.

The drainage system approach used for California highways is designed to maximize safety to the motoring public by avoiding flooding and to minimize maintenance activities that require lane closures which increase traffic congestion. By virtue of the linear nature of highways, the catchment area served by each local drainage system is relatively small, typically ranging from 1 to 10 acres. During storm events, runoff from the catchment area can carry litter, roadway deposited sediment, chemical constituents derived from various sources including vehicular exhausts, vegetative matter, and sediment from erosion of slopes. There is a concern that flows in these drainage systems deliver sediment and associated chemical constituents that may adversely affect the beneficial uses of downstream receiving waters.

Caltrans drain inlets typically include an inlet grate, drop structure, and drainage pipe that connects to a drainage outfall. The drain inlets are designed to be self-cleaning and not capture any solids or sediment, but the retention of debris can still occur.

To reduce the discharge of pollutants associated with its storm water drainage systems, Caltrans developed a Statewide Storm Water Management Plan (SWMP). The SWMP identifies how Caltrans will comply with the provisions of the National Pollutant Discharge Elimination System (NPDES) permit (Order No. 99-06-DWQ) (Permit) issued by the State Water Resources Control Board (SWRCB) on July 15, 1999. The Statewide SWMP addresses the primary program elements of all Caltrans activities:

- The Project Development Storm Water Management Program, which includes the Design Storm Water Management Program and the Construction Storm Water Management Program;
- The Maintenance Storm Water Management Program; and
- The Training and Public Education Program.

As part of the Maintenance Storm Water Management Program, Caltrans is committed to conducting a Baseline and Enhanced Storm Water Drainage Facilities Inspection and Cleaning Program (SWMP, Sections 5.3.2.1 & 5.3.2.2). Under the Baseline Storm Water Drainage Facilities Inspection and Cleaning Program, Maintenance Supervisors are responsible for inspecting storm water drainage systems and assessing the need for cleaning or clearing. Caltrans observes culverts and drain inlets annually in the fall and throughout the winter as needed to determine if cleaning or repairs are required. Culverts are cleaned when sediment impairs culvert function. Ditches are cleaned prior to the rainy season to maintain the hydraulic capacity of the ditch. Ditches and gutters are sealed or repaired when structural integrity is endangered. Downdrains are inspected annually and cleaned or repaired as necessary. Solid and liquid wastes generated by the cleaning of storm water drainage system facilities are disposed of in accordance with federal, state, and local liquid and solid waste disposal regulations. Baseline inspection and cleaning activities are reported annually by county, route, and postmile. This information is then used as a tool to evaluate the program.

An enhanced cleaning program has been conducted in southern California since 1995. In the fall of 1995, Caltrans cleaned all drain inlets in District 7, which covers an area that included roadways within Los Angeles and Ventura County. The total number of drain inlets cleaned was over 22,000. The drain inlet cleaning program has evolved from the initial 1995 cleaning to one of combined inspection and cleaning that included all drain inlets within District 7 from 1996 to 2002. Also under the enhanced program, in the metropolitan portions of San Diego, Orange and Ventura Counties, storm drain inlets are inspected and cleaned annually prior to the rainy season.

While continuing to conduct both baseline and enhanced drain inlet cleaning programs, Caltrans has been undertaking studies and data collection and analysis over a number of years to determine the effectiveness of drain inlet cleaning and to assist in determining an appropriate long-term approach to drain inlet maintenance, as discussed in Section 1.1.

1.3 Report Organization

The remainder of this report includes the following sections:

- **Section 2 – Drain Inlet Cleaning Efficacy Study** presents a description and the results of the DICE study.
- **Section 3 – Related Programs and Studies** summarizes the results and findings of both the STDS and all of the annual DIIC programs.
- **Section 4 – Drain Inlet Cleaning Effectiveness Assessment** synthesizes the results and findings of the above studies to provide an overall assessment of the effectiveness of drain inlet cleaning as a best management practice for Caltrans.
- **Section 5 – Conclusions** summarizes the findings of the study.

Section 2
Drain Inlet Cleaning Efficacy Study

2.1 Introduction

As noted in Section 1, Caltrans has been conducting the Drain Inlet Inspection and Cleaning (DIIC) Programs throughout Caltrans District 7 (i.e., the Los Angeles Basin). To evaluate the efficacy of the district-wide DIIC, Caltrans conducted a multi-year, comprehensive monitoring study during the 1996-1997 through 2000-2001 wet-weather seasons. In addition to water quality monitoring, Caltrans added a litter component to the study for 2000-2001. The Caltrans Drain Inlet Cleaning Efficacy Study Water Quality Monitoring Program (DICE Study) monitored from 8 to 12 sites per year during the five season period.

This section provides an overview of the DICE study and a summary of key results. For additional detailed study protocols, the Sampling and Analysis Plan for the 2000-2001 DICE Study is included in Appendix A. Detailed data and statistical analyses are presented in Appendices B and C.

2.2 DICE Study Objective

The overall objective of the DICE Study was to evaluate the potential effectiveness of drain inlet cleaning as a management practice for improving the water quality of highway storm water discharges. Specifically, the runoff discharge data collected has been used to determine if there is a significant difference in water quality between storm water discharged from catchments that were cleaned (test catchments) and storm water discharged from catchments that were not cleaned (control catchments). With the addition of the litter component to the DICE Study in the 2000-2001 wet weather season, the litter data was used to determine if there was a significant difference in the litter quantity and type in the storm water discharged from catchments that were cleaned, compared to storm water discharged from catchments that were not cleaned. Caltrans intends to use the results of this study to further develop management strategies to target storm water quality related issues and improve existing best management practices.

2.3 Study Design

The study approach involved selecting an even number of catchments (up to 12) within District 7 that were representative of typical highway catchments. Catchments were defined as the sections of highway, associated right-of-way, and offsite area (if any) that drain to a single discharge point. Discharges from highway catchments typically flow into municipal storm drain systems or directly into downstream receiving waters. For the DICE Study, each selected catchment consisted of a series of drain inlets that were connected through a network of storm drainage pipes along representative sections of highway located in Caltrans District 7.

To determine if there was a significant difference in water quality between storm water discharged from cleaned catchments and storm water discharged from un-cleaned catchments, the selected catchments were divided into two groups: the first group of catchments as used as the test catchments and the other group was used as the control catchments. All drain inlets in the test catchments were cleaned three times per season, at approximately six week intervals, whereas no drain inlet cleaning was performed in the control catchments. However, for the first monitoring season (1996-1997 wet weather season), the drain inlets were only cleaned two times.

Additionally, during the 1996-1997 monitoring season of the study, the six odd numbered catchments were used as the "test" catchments and the six even numbered catchments were used as the control catchments. For the second monitoring season, even numbered catchments were designated test catchments and odd numbered catchments were used as control catchments and the cleaning pattern reversed. This procedure was continued until the last season (2000-2001), when new catchments were monitored. The purpose of alternating test and control catchments was to eliminate bias in the data sets. A summary of the cleaned "test" catchments and un-cleaned "control" catchments is shown in Table 2-1.

To characterize the storm water discharging from the upstream drain inlets, water quality monitoring was performed at the discharge point of each of the catchments. Monitoring stations equipped with automated storm water samplers, flow meters, rainfall gauges, and remote programming technologies were installed at each outfall. The monitoring locations and the sampling and monitoring equipment installed at each outfall are discussed in Section 2.4. Flow-weighted composite samples were obtained at each outfall and analyzed for a variety of constituents typically present in highway runoff. Cleaning procedures, target analytes, and analytical methods are further discussed in Section 2.5 and 2.6. The analytical results from the test and control catchments were then compared to evaluate the effectiveness of drain inlet cleaning.

2.4 Sampling Locations and Equipment

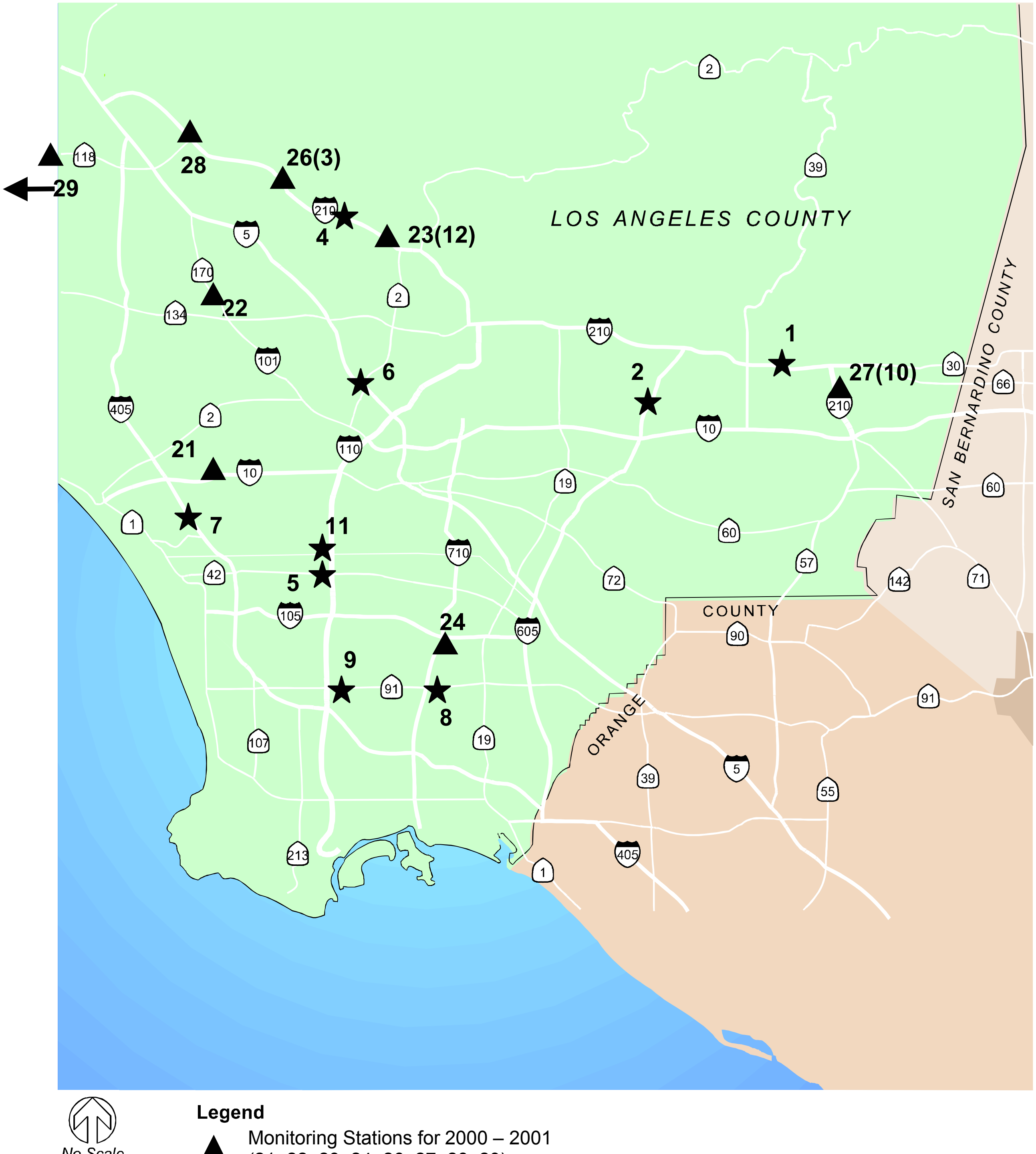
In 1996, 12 catchments within District 7 were selected as monitoring sites according to the site selection criteria discussed in the document, *Drain Inlet Monitoring Report and Effectiveness Assessment* (CTSW-RT-97-027, 1997). The selected monitoring sites were located throughout Los Angeles County as shown in Figure 2-1. Catchment areas 6 and 11 were not monitored during the 1997-1998 season due to various monitoring and safety issues observed during the 1996-1997 monitoring season. For the 1998-1999 season, the number of monitored sites was further reduced to eight with the discontinuation of monitoring at catchment areas 2 and 7, so that the study could focus on the sites with the most successful performance after two years of monitoring experience. For the 2000-2001 season, the objectives and monitoring goals were expanded to include litter monitoring. This required the identification of new catchment areas to be able to accommodate the litter collection apparatus. Three existing catchment areas and five new catchment areas were used for 2000-2001. Catchments 3, 10, and 12 from the previous years were retained and renumbered as 26, 27, and 23. Additionally, new catchments 21, 22, 24, 28, and 29 were added.

Table 2-1
Catchment Cleaning Schedule

Site	1996-1997	1997-1998	1998-1999	1999-2000	2000-2001
01	cleaned	uncleaned	cleaned	uncleaned	*
02	uncleaned	cleaned	*	*	*
03	cleaned	uncleaned	cleaned	uncleaned	renamed 26
04	uncleaned	cleaned	uncleaned	cleaned	*
05	cleaned	uncleaned	cleaned	uncleaned	*
06	uncleaned	*	*	*	*
07	cleaned	uncleaned	*	*	*
08	uncleaned	cleaned	uncleaned	cleaned	*
09	cleaned	uncleaned	cleaned	uncleaned	*
10	uncleaned	cleaned	uncleaned	cleaned	renamed 27
11	cleaned	*	*	*	*
12	uncleaned	cleaned	uncleaned	cleaned	renamed 23
21	--	--	--	--	cleaned
22	--	--	--	--	cleaned
23	--	--	--	--	uncleaned
24	--	--	--	--	uncleaned
26	--	--	--	--	cleaned
27	--	--	--	--	uncleaned
28	--	--	--	--	uncleaned
29	--	--	--	--	cleaned

Note:

*Discontinued



Legend

▲ Monitoring Stations for 2000 – 2001 (21, 22, 23, 24, 26, 27, 28, 29)

★ Monitoring Station for 1996 - 2000 (1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12)

Figure 2-1
Monitoring Station Network

Table 2-2 presents characteristics of each catchment. For each catchment, the table identifies the monitoring station number, location, type of highway within the catchment area, number of drain inlets, and catchment area.

The monitoring and sampling equipment installed at each monitoring station was selected to achieve water quality monitoring objectives. Specific monitoring location characteristics such as channel geometry and design, overhead obstructions, and proximity to a direct power source dictated which monitoring technology was most suitable for each monitoring station. Initially, the equipment installed at each station included an autosampler, a flow meter, a power source, and cellular phone telemetry capability. Flow meters and power sources varied from site to site. Eight out of the initial 12 stations were equipped with rain gauges. Rain gauges were not installed at four stations due to overhead obstructions. A typical original monitoring station setup is shown in Figure 2-2.

Table 2-2
Catchment Characteristics

Catchment Number(1)	Monitoring Location	Freeway/ Post Mile	Type of Freeway (Cut/Fill)	Total No. of Drain Inlets	Catchment Area (hectares)
1	Eastbound 210 Freeway at Citrus Ave. on-ramp	210/40.8	Cut	24	4.8
2	Southbound 605 Freeway at Ramona Ave. off-ramp	605/21.27	Fill	10	4.1
3 (26)	Westbound 210 Freeway at the Big Tujunga Wash	210/10.12	Cut/Fill	38	12.6
4	Eastbound 210 Freeway at the Holy Redeemer Catholic School	210/18.13	Cut	38	12.8
5	Northbound 110 Freeway at Manchester Ave. on-ramp	110/15.92	Fill	11	1.4
6	Under the 5 and 110 Freeway Interchange at the Arroyo Seco Channel	5/20.39	Fill	10	1.0
7	Northbound 405 Freeway at Havelock Ave.	405/26.78	Fill	9	2.1
8	Eastbound 91 Freeway at the Paramount Blvd. off-ramp	91/13.59	Cut/Fill	6	1.0
9	Westbound 91 Freeway, West of Wilmington Ave.	91/8.92	Cut	4	1.6
10 (27)	Westbound 210 Freeway at Gladstone St.	210/44.91	Fill	9	3.6
11	Southbound 110 Freeway at the Florence Ave. off-ramp	110/44.91	Fill	9	2.1
12 (23)	Eastbound 210 Freeway at the Ocean View Blvd. on-ramp	210/18.45	Cut	20	2.9
21	Westbound 10 Freeway at Fairfax off-ramp	10/9.9	Fill	6	0.5
22	Northbound 170 Freeway at Oxnard off-ramp	170/16.2	Fill	7	0.9
24	Southbound 710 Freeway, south of the 105	710/15.6	Fill	5	2.9
28	Eastbound 210 Freeway at 118 Interchange	210/6.0	Fill	6	2.8
29	Eastbound 118 Freeway at Topanga Canyon (27)	118/1.6	Fill	3	0.8

Note:

1 Catchment numbers over 20 were used during the 2000-2001 monitoring season.

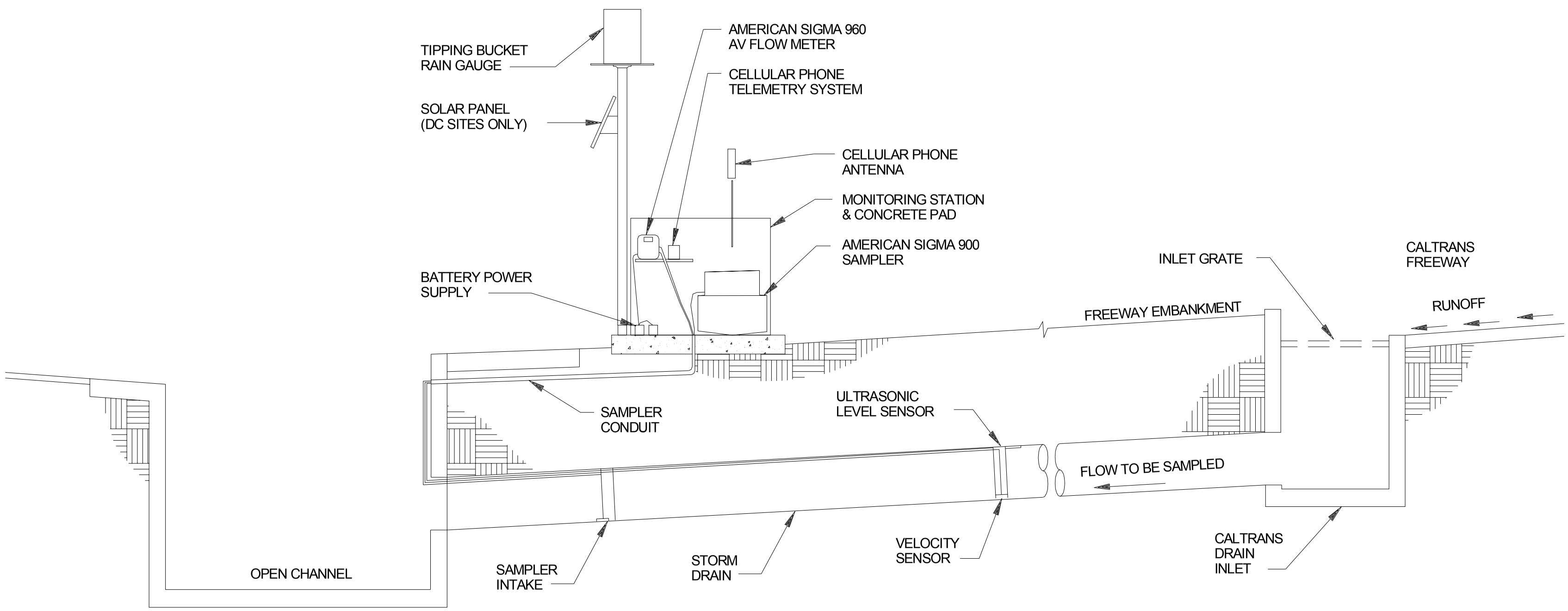


Figure 2-2
Caltrans Drain Inlet Cleaning Efficacy Study
Typical Stormwater Monitoring Station

In the last season of monitoring, 2000-2001, the scope was amended to include litter monitoring. A litter protective enclosure was attached to the downstream discharge point and ¼ inch. mesh litter bags were fitted over the downstream pipe. A typical station set-up for water quality and litter monitoring is shown in Figure 2-3.

2.5 Cleaning and Analytical Methods

Drain inlet cleaning was performed for the DICE Study to remove all materials present in the inlets and the accessible portion of the lateral pipes. The materials removed typically included sediment, vegetation, and litter. The inlets were cleaned using heavy duty industrial vacuum trucks equipped with an 8-inch suction hose. A subcontractor performed the actual drain inlet cleaning. This cleaning effort is essentially identical to the practice employed by District 7 for the District-wide cleaning program. As previously mentioned, catchments were cleaned every other year to eliminate bias in the data sets.

To further evaluate the efficacy of drain inlet cleaning, the mass of material removed from each catchment during each cleaning was estimated and observations documented. The mass of the material removed from each catchment was measured in the following manner:

- A single vacuum truck and crew was assigned to clean all drain inlets within each test catchment.

- The empty (tare) weight of the truck with full fuel tanks was measured at a truck scale prior to the start of the cleaning operations.

- After all inlets in a particular catchment were cleaned, the truck was re-fueled and re-weighed. The difference in the total weight of the truck before and after cleaning provided the weight of material removed from the cleaned catchment.

As part of the cleaning routine, each drain inlet was inspected prior to cleaning. Field crews were required to fill out a standardized field form. This form included information on the location of the inlet, inlet dimensions, depth of material, roadway configuration, presence of a soundwall or other barriers, and vegetation coverage.

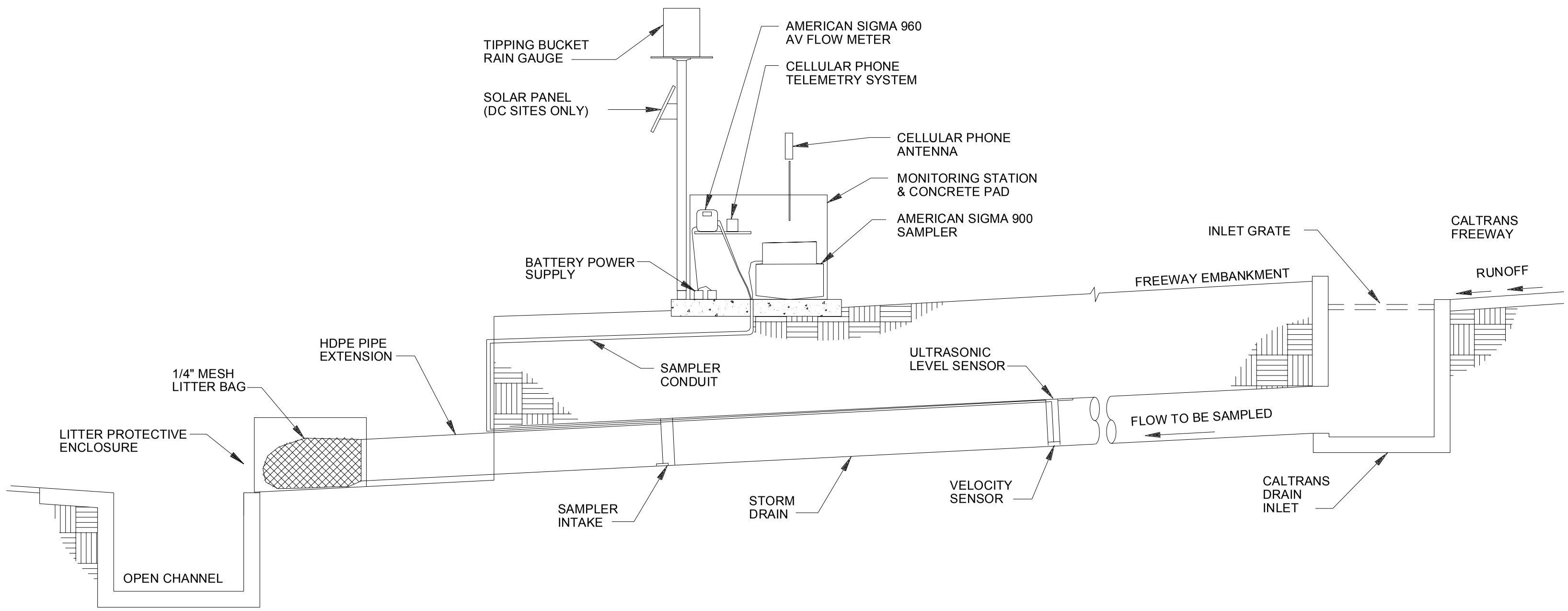


Figure 2-3
Caltrans Drain Inlet Cleaning Efficiency Study Typical Stormwater & Litter Monitoring System

2.6 Analytical Methods

The storm water sampling method used for the DICE Study was designed to provide an event mean concentration (EMC) for the parameters of interest. The EMC represents the average concentration of a given parameter over a single runoff event. A true EMC would be obtained if all the runoff from a given event could be collected, thoroughly mixed, and analyzed. However, capturing the entire runoff event for analytical analysis is typically not possible or practical.

To generate an approximation of the EMC, a series of discrete samples can be collected over the course of a runoff event and combined into a single composite sample. When the composite sample is analyzed, the results can be equated to the EMC for the runoff event.

The compositing of discrete samples must be conducted on a flow-proportioned or flow-weighted basis. Developing a flow-weighted composite was accomplished by collecting the discrete samples every time a set volume of runoff passed by. This volume remained constant throughout the entire event and was known as the "trigger volume." For example, if the trigger volume was set at 5,000 cubic feet, a discrete sample was collected every time the flow meter measured this volume had passed by. When this criterion was met, the flow meter would send a signal to the automatic sampler to collect a sample.

The flow meter was interfaced with an autosampler at each monitoring station. Each auto sampler was equipped with eight 2.3-liter polyethylene sample bottles. When signaled by the flow meter, each auto sampler was pre-programmed to collect a 500-milliliter (mL) sample. Up to four discrete samples were delivered to each bottle. Based on this configuration, a total of 32 discrete samples (8 bottles/4 samples per bottle) could be collected before the bottles had to be removed and replaced with clean empty bottles.

The suite of parameters monitored varied from season to season. Conventional pollutants, metals, and nutrients were monitored every year. The target parameters for the last monitoring season, 2000-2001, are presented in Table 2-3.

2.7 Drain Inlet Cleaning Data

2.7.1 1996-1997 Monitoring Season

During 1996-1997 drain inlet cleaning activities, the following observations were made:

- Approximately 90 percent of the cleaned inlets contained some material during the first cleaning (debris, trash, or sediment).
- Approximately 70 percent of the cleaned inlets contained some material during the second cleaning (debris, trash or sediment).
- At catchments 1 and 9, sediments were observed in the lateral pipes during both the first and second cleanings.

Table 2-3 List of Target Parameters Caltrans Drain Inlet Cleaning Efficacy Study Water Quality Monitoring Program					
Parameter	**Sampling Method**	**EPA Method**	**Units**	**Laboratory Reporting Limit**	**Holding Times**
Metals (Total and Dissolved)					
Arsenic	Automatic Sampler	200.8	µg/L	0.5	6 months
Cadmium	Automatic Sampler	200.8	µg/L	0.2	6 months
Chromium	Automatic Sampler	200.8	µg/L	1	6 months
Copper	Automatic Sampler	200.8	µg/L	1	6 months
Lead	Automatic Sampler	200.8	µg/L	1	6 months
Nickel	Automatic Sampler	200.8	µg/L	1	6 months
Zinc	Automatic Sampler	200.8	µg/L	5	6 months
Nutrients					
Nitrate-N	Automatic Sampler	300.0	mg/L	0.1	48 hours
Total Phosphorus	Automatic Sampler	365.3	mg/L	0.03	28 days
Dissolved Phosphorus	Automatic Sampler	365.3	mg/L	0.03	28 days
TKN	Automatic Sampler	351.3	mg/L	0.1	28 days
Dissolved Ortho Phosphate	Automatic Sampler	365.3	mg/L	0.03	48 hours
General					
Temperature	Field Measurement		^{o}C	0.1	15 min.
PH	Automatic Sampler	150.1	standard units	0.01	24 hours
Total Hardness	Automatic Sampler	130.2	mg/L	2	6 months
Specific Conductivity (EC)	Automatic Sampler	120.1	µmhos/cm	1	28 days
Total Organic Carbon	Automatic Sampler	415.1	mg/L	1	28 days
Dissolved Organic Carbon (DOC)	Automatic Sampler	415.1	mg/L	1	28 days
Total Suspended Solids (TSS)	Automatic Sampler	160.2	mg/L	1	7 days
Total Dissolved Solids (TDS)	Automatic Sampler	160.1	mg/L	1	7 days
Volatile Solids	Automatic Sampler	160.4	mg/L	1	48 hours

- At catchment 11, as a result of trash and debris accumulation on a trash rack located near the outfall, the outfall and some of the lateral pipes were observed to be completely plugged during both the first and second cleanings.

- The 1996-1997 drain inlet cleaning results are summarized in Table 2-4. The table includes the total mass of material removed, the mass of material removed per cleaned inlet, the mass of material removed per hectare of drainage area, and the range of reported sediment depths within each inlet. The total mass of material removed during the first cleaning was 6,799 kg. During the second cleaning, 2,561 kg of material were removed.

Observations of the cleaning data include:

- The mass of material removed decreased substantially between the first and second cleaning.

Table 2-4
Summary of the 1996-1997 Drain Inlet Cleaning Results

Catchment Number	Area (ha)	Number of Inlets	Number of Inlets with Material Removed	Mass of Material Removed (kg)	Mass of Material per Cleaned Inlet (kg/inlet)	Mass of Material per Hectare (kg/ha)	Range of Reported Sediment Depths (cm)[1]
First Cleaning - December 13, 1996							
1	4.8	24	24	518	22	108	2.5 - 61
3	12.6	38	38	745	20	59	2.5 – 30.5
5[2]	1.4	11	8	918	83	648	2.5
7[3]	2.1	9	4	509	57	237	2.5 – 5.1
9	1.6	4	3	973	243	616	2.5
11	2.1	9	9	3136	348	1,489	15.2 - 122
Totals		95	86	6,800			
Second Cleaning - February 6, 1997							
1	4.8	24	24	359	15	75	1.3 – 15.2
3	12.6	38	16	418	11	33	2.5 – 10.2
5	1.4	11	8	73	7	51	2.5
7	2.1	9	6	91	10	42	1.3 – 2.5
9[d]	1.6	4	4	320	80	203	1.3
11	2.1	9	9	1,300	144	617	5.1 – 15.2
Totals		95	67	2,561			

Notes:

[1] Derived from the Drain Inlet Cleaning Field Forms
[2] The catchment area and the number of inlets within the catchment were reassessed during the 1997-1998 monitoring season. Based on the results, the drainage area was revised from 0.7 to 1.4 hectares and the number of inlets from 9 to 11. Therefore, it should be noted that 2 inlets within the catchment were not inspected during the 1996-1997 DICE Study.
[3] Only 7 of the 9 drain inlets were inspected due to time constraints.
[4] An additional inlet was cleaned during DI cleaning which was outside of the catchment area (4 in the catcment/1 outside the catchment).
Therefore, the "Mass of Material Removed" was estimated based on (4/5)*(total mass removed = 400 kg).

- The mass of material removed was highest from catchment 11 for both cleanings. Moreover, half the total material recovered was removed from catchment 11. As previously noted this catchment was observed to be prone to clogging due to the location and design of the trash rack.

- The mass of material removed per inlet decreased substantially between the first and second cleaning at all catchments.

- On a mass per inlet basis, catchments 11 and 9 were substantially higher than catchments 1, 3, 5, and 7 during both rounds of cleaning.

- The mass of material removed per hectare decreased substantially between the first and second cleaning at all catchments.

From the 1996-1997 cleanings, the sediment was predominantly coarse grained with a small fraction (less than 10 percent) of silt and clay material taken from the inlets in catchments 1, 3, 5, and 11. Sediment removed from the inlets in catchments 7 and 9 had a higher percentage of silt and clay material (up to 30 percent).

In general, the particle size distributions did not change substantially between cleaning. However, sediment removed from catchment 7 during the first cleaning had a higher percentage of silt and clay than the sediment removed during the second cleaning. Inversely, catchment 9 had a higher percentage of silt and clay in the sediments removed during the second cleaning.

2.7.2 1997-1998 Monitoring Season

During 1997-1998 drain inlet cleaning activities, the following observations were made:

- Seventy-nine percent of the cleaned inlets contained some material during the first cleaning (debris, trash, or sediment).
- Twenty-three percent of the cleaned inlets contained some material during the second and third cleaning.
- During the second and third cleaning no material was removed from catchment 10.

The 1997-1998 drain inlet cleaning results are summarized in Table 2-5. The table includes the total mass of material removed, the mass of material removed per cleaned inlet, and the mass of material removed per hectare of drainage area, and the range of reported sediment depths within each inlet. The total mass of material removed during the first cleaning of the 1997-1998 season was 2950 kg. During the second cleaning, the total mass removed was 967 kg. The third cleaning removed 1672 kg of materials. From the table, the following observations were made.

- The mass of material removed decreased substantially between the first and second cleanings and the first and third cleanings at all catchments except 8.
- Approximately 50 percent of the total material recovered during the second cleaning was removed from catchment 12.
- Approximately 77 percent of the total material recovered during the third cleaning was removed from catchment 8.
- The mass of material removed during the 1997-1998 monitoring season was only 60% of the mass removed during 1996-1997, even though the number of inlets cleaned was similar (i.e., 84 vs. 95) and the inlets were cleaned three times rather than twice.

Table 2-5
Summary of the 1997-1998 Drain Inlet Cleaning Results

Catchment Number	Area (ha)	Number of Inlets	Number of Inlets with Material Removed	Mass of Material Removed (kg)	Mass of Material per Inlet (kg/inlet)	Mass of Material per Hectare (kg/ha)	Range of Reported Sediment Depths (cm)[1]
First Cleaning - November 1 and 7, 1997							
2	4.1	10	7	845	85	206	5.1 – 7.6
4	12.8	38	34	1,055	28	82	2.5 – 20.3
8 [2]	1.0	7	6	195	28	195	5.1 – 27.9
10	1.5	9	3	55	6	37	7.6 – 12.7
12	2.9	20	16	800	40	276	5.1- 20.3
Totals		84	66	2,950			
Second Cleaning - January 17, 1998							
2	4.1	10	1	18	2	4	0 – 5.1
4 [3]	12.8	38	6	422	11	33	0 – 7.6
8	1.0	7	2	41	6	41	0 – 3.8
10	1.5	9	0	0	0	0	0
12	2.9	20	10	486	24	168	0 – 15.2
Totals		84	19	967			
Third Cleaning - March 7, 1998							
2	4.1	10	1	45	5	11	0 – 3.8
4	12.8	38	9	200	5	16	0 – 12.7
8	1.0	7	2	1,286	184	1,286	0 – 70
10	3.6	9	0	0	0	0	0
12	2.9	20	7	141	7	49	5.1 – 7.6
Totals		84	19	1,672			

Notes:

1 Derived from the Drain Inlet Cleaning Field Forms.
2 Two additional inlets were cleaned during DI cleaning which were outside of the catchment area (6 in the catchment/2outside the catchment). Therefore the "Mass of Material Removed" was estimated based on (6/8)*(total mass removed = 259 kg.)
3 The "Mass of Material Removed" was estimated by calculating the volume of material removed from each catchment. Volume (cubic meter) was calculated from the depth of material within each inlet and the known dimensions of the inlet. The mass (kg) was then estimated by multiplying the estimated volume by the estimated specific density of typical freeway sediments (1174 kg/m^3) based on the Gravimetric Sediment Analysis conducted by Caltrans in January 1997.

The particle size distributions did not change between cleanings. At catchments, 2, 4, 10, and 12, the sediments were predominantly medium grained sand fractions for each cleaning. Sediments removed from catchment 8 during the first and second cleaning were predominantly fine-grained sand fractions. However, sediments removed during the third cleaning were predominantly medium grained sand fractions.

2.7.3 1998-1999 Monitoring Season

During 1998-1999 drain inlet cleaning activities, the following observations were made:

- Approximately 94 percent of the cleaned inlets contained some material during the first cleaning (debris, trash, or sediment).

- Approximately 57 percent of the cleaned inlets contained some material during the second cleaning (debris, trash, or sediment).

- Approximately 62 percent of the cleaned inlets contained some material during the third cleaning (debris, trash, or sediment).

- At catchment 1, sediment was observed in the lateral pipes during all three cleanings.

- At catchment 5, no sediment was observed in inlets during the second cleaning.

The 1998 - 1999 drain inlet cleaning results are summarized in Table 2-6. The table includes the total mass of material removed, the mass of material removed per inlet, the mass of material removed per hectare of drainage area, and the range of reported sediment depths within each inlet. The total mass of material removed during the first cleaning was 1627 kg. During the second cleaning 1009 kg of material as removed and 713 kg of material was removed during the third round of cleaning.

The 1998 - 1999 drain inlet cleaning results included the following observations:

- The mass of material removed during the 1998-99 monitoring season was about 60% and 46%, respectively, of the mass removed in the 1997-98 and 1996-1997 monitoring seasons.

- The mass of material removed and the mass of material removed per hectare was considerably higher from catchment 1 for all three cleanings, except for the first cleaning from catchment 9. Moreover, more than half of the total material recovered for all the cleanings was removed from catchment 1.

- The mass of material removed per inlet and removed per hectare decreased considerably between the first and second cleaning at catchments 1, 5, and 9, while slightly increasing between the first and second cleanings at catchment 3.

The sediment removed during the 1998-1999 DICE Study was predominantly medium to fine sands with a small fraction of gravel material. At catchments 1 and 3, the sediment removed during the first and second rounds of cleaning was predominantly medium grained sand fractions. During the third round of cleanings, removed sediment was predominantly medium to coarse grained sands. Sediment removed from catchments 5 and 9 was predominantly medium to fine grained sands.

Table 2-6
Summary of the 1998-1999 Drain Inlet Cleaning Results

Catchment Number	Area (ha)	Number of Inlets	Number of Inlets with Material Removed	Mass of Material Removed (kg)	Mass of Material per Inlet (kg/inlet)	Mass of Material per ha (kg/ha)	Range of Reported Sediment Depths (cm)[1]
First Cleaning - November 18-20, 1998							
1	4.8	24	24	1,059	44	221	2.5 – 61
3	12.6	38	38	173	5	14	2.5 – 30.5
5	1.4	11	8	86	8	61	2.5
9	1.6	4	3	309	77	193	2.5
Totals		77	73	1,627			
Second Cleaning - January 19-20, 1999							
1	4.8	24	19	618	26	129	2.5 – 15.2
3	12.6	38	21	323	8	26	2.5 – 7.6
5	1.4	11	0	0	0	0	2.5
9	1.6	4	4	68	17	43	2.5
Totals		77	44	1,009			
Third Cleaning - March 23-24, 1999							
1	4.8	24	24	550	23	115	1.3 – 12.7
3	12.6	38	15	59	2	5	1.3 – 5.1
5	1.4	11	5	9	1	6	0.8 – 7.6
9	1.6	4	4	95	24	59	1.3 – 3.8
Totals		77	48	713			

Note:
[1] Derived from the Drain Inlet Cleaning Field Forms.

2.7.4 1999-2000 Monitoring Season

During 1999-2000 drain inlet cleaning activities, the following observations were made:

- Ninety-seven percent of the cleaned inlets contained some material during the first cleaning (debris, trash, or sediment).
- Sixty-three percent of the cleaned inlets contained some material during the second cleaning (debris, trash or sediment).
- Forty-nine percent of the cleaned inlets contained some material during the third cleaning (debris, trash, or sediment).
- At catchment 8, sediment was observed in the lateral pipes during all three cleanings.
- At catchment 10, no sediment was found in any of the six drain inlets during the second and third cleanings.

A summary of the 1999 - 2000 drain inlet cleaning results is presented in Table 2-7. The table includes the total mass of material removed, the mass of material removed per cleaned inlet, the mass of material removed per hectare of drainage area, and the range of reported sediment depths within each inlet. The total mass of material removed during the first cleaning was 2423 kg. During the second cleaning, 331 kg of material were removed and 311 kg of material during the third round of cleaning. The 1999 - 2000 drain inlet cleaning results included the following observations:

Table 2-7
Summary of the 1999-2000 Drain Inlet Cleaning Results

Catchment Number	Area (ha)	Number of Inlets	Number Of Inlets with Material Removed	Mass of Material Removed (kg)	Mass of Material per Inlet (kg/inlet)	Mass of Material per Ha (kg/ha)	Range of Reported Sediment Depths (cm)[1]
First Cleaning - November 10-11, 1999							
4	12.8	38	38	1,173	31	92	2.5 – 45.7
8	1.0	6	4	91	15	91	2.5 – 30.5
10	1.2	6	6	141	24	118	2.5 – 7.6
12	2.9	20	20	1,018	51	351	2.5 – 30.5
Totals		70	68	2,423			
Second Cleaning - January 5-6, 2000							
4	12.8	38	28	227	6	18	1.3 – 10.2
8	1.0	6	4	45	8	45	1.3 – 5.1
10	1.2	6	0	0	0	0	N/A
12	2.9	20	12	59	3	20	1.3 – 5.1
Totals		70	44	331			
Third Cleaning - March 14-15, 2000							
4	12.8	38	20	145	4	11	1.3 – 10.2
8	1.0	6	2	2	0.3	2	1.3
10	1.2	6	0	0	0	0	N/A
12	2.9	20	12	164	8	57	1.3 – 5.1
Totals		70	34	311			

Note:
[1] Derived from the Drain Inlet Cleaning Field Forms.

- The mass removed per inlet was approximately the same as in the 1998-99 monitoring season.
- The mass of material removed and the mass of material removed per inlet was higher from catchments 4 and 12. Moreover, 91% of the total material recovered for all the cleanings was removed from catchments 4 and 12.
- The mass of material removed per inlet and per hectare at all four catchments decreased considerably between the first and second cleaning.

The sediment removed during the 1999-2000 DICE Study was predominantly medium to fine sands with a small fraction of gravel material. At catchments 4 and 12, the sediment removed during the first and second rounds of cleaning predominantly medium grained sand fractions. During the third round of cleanings, removed sediment predominantly medium to fine grained sands. Sediment removed from catchments 8 and 10 predominantly medium to fine grained sands during all three rounds.

2.7.5 2000-2001 Monitoring Season

During 2000-2001 drain inlet cleaning activities, the following field observations were made:

- Fifty-two percent of the cleaned inlets contained some material during the first cleaning (debris, trash, or sediment).
- One hundred percent of the cleaned inlets contained some material during the second cleaning (debris, trash or sediment).
- Forty percent of the cleaned inlets contained some material during the third cleaning (debris, trash, or sediment).

Table 2-8 includes the total mass of material removed, the mass of material removed per inlet, the mass of material removed per hectare of drainage area, and the range of reported sediment depths within each inlet. The total mass of material removed during the first cleaning was 763 kg. During the second cleaning, 454 kg of material was removed plus the quantity removed from the 38 inlets at catchment 26, for which mass data was not available. During the third round of cleaning, 616 kg of material was removed.

Analysis of the 2000-2001 drain inlet cleaning results included the following observations:

- The total mass of material removed varied among the four catchments. No one catchment dominated in total mass, mass per inlet, or mass per hectare.
- The total mass of material removed was the lowest of all of the monitoring seasons.

The sediment removed during the 2000-2001 DICE Study was predominantly medium to fine sands with a small fraction of gravel material. At catchments 22 and 29, the sediment removed during all three rounds of cleaning was predominantly fine grained sand fractions. At catchment 26, the sediments removed during all three rounds of cleaning mostly medium grained sands. Sediment were removed from catchment 10 was fine grained sands during the first cleaning, but medium grained sands during the second and third round of cleaning.

Table 2-8
Summary of the 2000-2001 Drain Inlet Cleaning Results

Catchment Number	Area (hectares)	Number of Inlets	Number Of Inlets with Material Removed	Mass of Material Removed (kg)	Mass of Material per Inlet (kg/inlet)	Mass of Material per Area (kg/ hectare)	Range of Reported Sediment Depths (cm)[1]
First Cleaning - October 30-31, 2000							
21	0.5	6	6	313	52	626	5 - 13
22	0.9	7	5	168	24	187	1 - 10
26	12.6	38	14	132	3	10	2.5 – 10
29	0.8	3	3	150	50	188	5
Totals		54	28	763			
Second Cleaning – January 8-9, 2001							
21	0.5	6	6	172	29	344	5 – 13
22	0.9	7	7	236	34	262	5 – 10
26	12.6	38	38	NA	NA	NA	1 – 10
29	0.8	3	3	45	15	56	2.5 - 10
Totals		54	54	NA			
Third Cleaning - March 8-9, 2001							
21	0.5	6	1	9	2	18	1
22	0.9	7	4	272	39	302	5 - 13
26	12.6	38	15	290	8	23	1 - 3
29	0.8	3	3	45	15	56	1 - 3
Totals		54	23	616			

Note:
[1] Derived from the Drain Inlet Cleaning Field Forms
NA – Not Available

2.7.6 Historical Evaluation

Total mass of material removed during each of the five monitoring seasons is summarized in Table 2-9. The data from catchments 2, 6, 7, and 11 has been excluded from this analysis since these catchments were discontinued after the second study years. General observations from Table 2-9 show that the greatest mass of solids removed during a single round of cleaning was always from the first round for all five seasons. During the 1997-1998 seasons, the second round of cleaning removed the lowest total mass for the three cleanings.

When evaluating the five-year DICE study on a solids-removed-per inlet basis, the data shows a substantial overall decline from year-to-year, except for the 1999-2000 study year. Figure 2-4 also shows how the mass per inlet removed for the second and third cleanings was always lower than the first cleaning during each year of study.

A comparison between second and third cleanings shows that the mass per inlet removed for the third cleaning was generally lower than the second cleaning, except for the 1997-1998 cleaning year. In 1996-1997, only two cleanings were conducted. Additionally, the mass per inlet removed for the second cleaning for 2000-2001 was not available due to missing data for the second cleaning at Catchment 26.

Table 2-9
Summary of the Drain Inlet Cleaning Results for the DICE Study

Monitoring Season	Total Mass (kg)	Round 1 (kg)	Round 2 (kg)	Round 3 (kg)
2000-2001 [1]	NA [2]	346	NA [3]	280
1999-2000 [2]	3,063	2,420	331	360
1998-1999 [5]	3,346	1,625	1,008	1,570
1997-1998 [4, 6]	4,676	2,102	949	3,580
1996-1997 [5, 6]	4,318	3,151	1,169	

Notes:

1 Inlets from catchments 21, 22, 26, and 29 were cleaned.
2 NA – Not available.
3 Data for catchment 26 was unavailable for Round 2 cleaning due to missing data.
4 Inlets from the even number catchments were cleaned (4, 8, 10, and 12).
5 Inlets from the odd number catchments were cleaned (1, 3, 5, and 9).
6 Includes results only from the inlets cleaned during first four seasons.

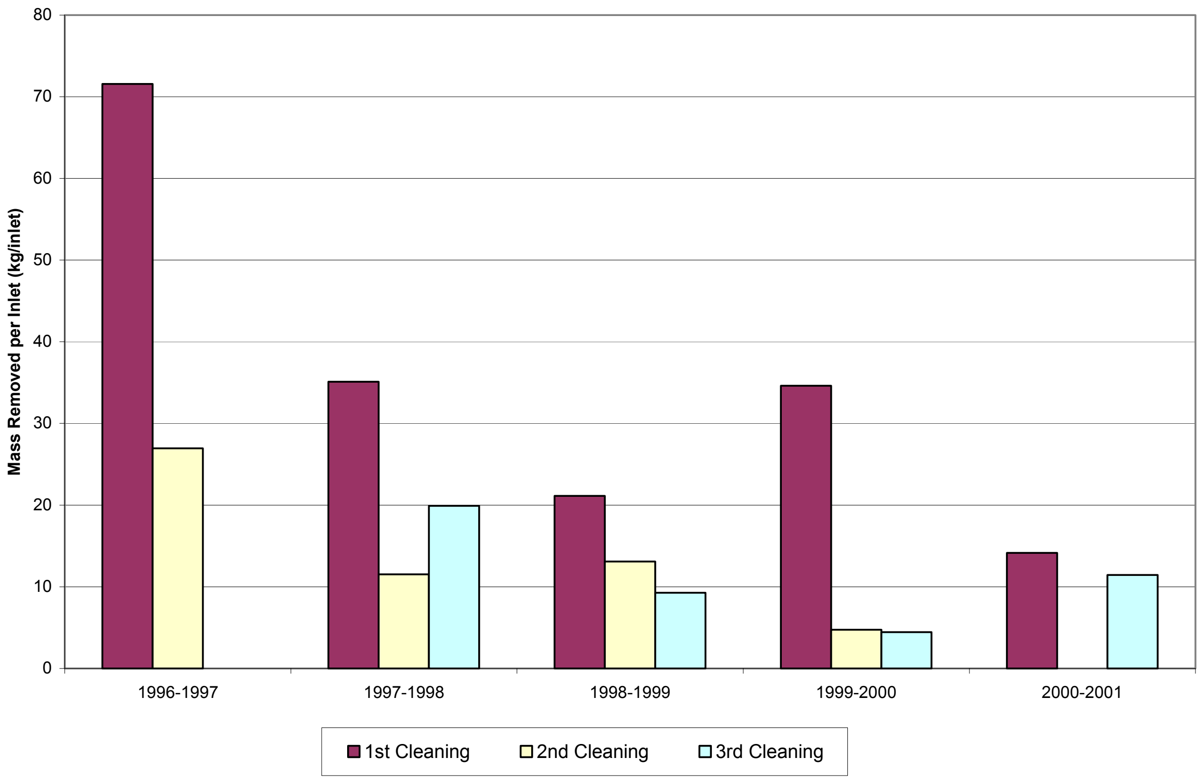


Figure 2-4
Comparison of Solids Removed During 5-Year DICE Study

2.8 Water Quality Data

The tables included in Appendix B summarize the detailed analytical data generated from the five years of monitoring data. The data are presented on the basis of cleaned and uncleaned catchments for each parameter. The data summaries include the number of samples, the mean of all event mean concentration (EMC) data, and maximum and minimum EMC values. The EMC represents the flow-weighted composite concentration of a given parameter over a single runoff event. Only the data meeting the quality objectives of the project were used to generate this summary.

Table 2-10 shows the DICE Study combined 1996-1997 through 2000-2001 data, and compares it to the most stringent water quality objectives (WQO) based on the Basin Plan, California Toxics Rule, and the California Ocean Plan, as cited in the Caltrans Statewide Storm Water Management Plan (SWMP), August 2000. The California Toxics Rule Criteria (CTR) for toxic pollutants was developed by USEPA in May 2000. The California Ocean Plan was updated by the State Water Resources Control Board in 2001. Caltrans monitoring data for highway runoff for 1998-2001 is also presented as a means of assessing the representativeness of the DICE Study runoff data.

As an additional means for comparison, the USEPA maximum contaminant levels (MCLs) for drinking water contaminants is used to evaluate the nitrate as nitrogen parameter.

2.8.1 Water Quality Observations

A comparison of the water quality between the DICE study and Caltrans highway runoff data shows that the mean of the EMCs for the DICE Study compares well when considering means and the standard deviations of the concentrations for Caltrans highway runoff data. For example, total copper for DICE was determined to be 39.87 µg/L and 27.81 µg/L for cleaned and uncleaned inlets, respectively. For Caltrans highway runoff data (1998-2001), total copper had a reported mean concentration of 48.1 µg/L with a standard deviation of 412.5 µg/L.

When DICE and general Caltrans highway runoff water quality data are compared with stringent receiving water quality objectives, several constituents are observed as exceeding the criteria including dissolved chromium, copper, lead and zinc. Therefore, a key indicator of the effectiveness of drain inlet cleaning is the ability to significantly reduce the concentrations of these metals.

Table 2-10
Comparison of Water Quality Results for DICE Study 1996-1997 through 2000-2001 Combined Data with Applicable Water Quality Criteria and Caltrans Highway Runoff for 1998-2001

Constituent	DICE Study Combined Data 1996-1997 to 2000-2001								Water Quality Objectives [1]	Caltrans Monitoring Data for Highway Runoff 1998-2001 [2]
	Cleaned Inlets				Uncleaned Inlets					
	Mean	Median	Max	Min	Mean	Median	Max	Min		Mean
Total Metals	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)
Arsenic [3]	0.79	NA	3.42	0.50	1.23	NA	2.85	0.50	N/A	1.99
Cadmium	1.03	0.79	13.00	0.10	1.02	0.90	7.10	0.10	N/A	0.84
Chromium	8.08	5.80	100.00	0.46	8.35	6.00	57.00	1.00	N/A	9.3
Copper	39.87	27.00	770.00	3.30	27.81	26.10	280.00	2.10	N/A	48.1
Nickel	5.9	6.00	130.00	0.91	10.33	7.00	175.00	1.00	N/A	11.4
Lead	68.19	38.00	700.00	4.50	43.94	40.00	690.00	1.10	N/A	62.6
Zinc	143.18	139.00	2400.00	21.00	186.16	140.00	1400.00	11.00	N/A	208.3
Dissolved Metals										
Arsenic [3]	0.59	NA	2.44	0.50	1.18	NA	2.82	0.50	50	1.06
Cadmium	0.45	0.40	3.10	0.03	0.49	0.40	6.10	0.02	2.2 [1a]	0.24
Chromium	2.28	2.00	15.00	0.55	2.46	2.10	10.00	0.73	2	2.9
Copper	9.76	10.00	76.00	1.60	10.31	10.00	76.00	1.50	3.1	15.2
Nickel	2.91	2.00	20.00	0.47	3.47	2.00	36.00	0.52	5	4.5
Lead	5.24	2.10	42.00	0.20	6.86	2.74	84.00	0.34	2	5.4
Zinc	55.00	57.00	720.00	9.00	60.05	64.00	330.00	2.00	20	72.2
Conventionals										
Hardness (mg/L)	36.63	37.00	365.00	3.30	60.87	44.00	448.00	10.00	NA	46.2
Nitrate-as N (mg/L)	0.84	NA	2.52	0.29	0.93	NA	2.68	0.33	10 [1b]	1.1
Total-N (mg/L)	0.81	0.77	4.20	0.19	1.10	0.91	3.30	0.24	NA	NA
TKN (mg/L)	1.85	1.10	57.00	0.10	1.52	1.20	11.30	0.10	NA	2.3
Phosphorus-Dissolved (mg/L)	0.12	0.10	0.81	0.02	0.14	0.10	0.74	0.01	NA	0.2
Phosphorus-Total (mg/L)	0.21	0.17	1.20	0.01	0.24	0.20	1.00	0.02	NA	0.4

Table 2-10
Comparison of Water Quality Results for DICE Study 1996-1997 through 2000-2001 Combined Data with Applicable Water Quality Criteria and Caltrans Highway Runoff for 1998-2001

Constituent	DICE Study Combined Data 1996-1997 to 2000-2001								Water Quality Objectives [1]	Caltrans Monitoring Data for Highway Runoff 1998-2001 [2]
	Cleaned Inlets				Uncleaned Inlets					
	Mean	Median	Max	Min	Mean	Median	Max	Min		Mean
TSS (mg/L)	97.12	56.00	983.00	10.00	74.24	70.00	1230.00	9.00	NA	147.3
TOC (mg/L)	7.42	7.50	51.00	0.60	8.68	8.30	50.60	1.60	NA	21.0
Total Volatile Solids (mg/L)	45.28	36.50	274.00	1.00	48.13	42.00	136.00	1.00	NA	NA
Specific Conductivity (uhms/cm)	76.47	70.90	458.00	18.00	124.11	84.70	923.00	28.10	NA	215.2

Note:

[1] Most stringent water quality objectives based on the Basin Plan, California Toxics Rule and the Ocean Plan, as reported in the in the Caltrans Statewide Storm Water management Plan
[1a] Function of the total hardness in the water body. Total hardness is assumed to be 100 mg/L.
[1b] Maximum contaminant levels (MCLs) for drinking water contaminants, USEPA, November 2002.
[2] Mean values from Summary of Caltrans Monitoring Data for Highway Runoff, 1998-2001.
[3] Concentrations for Arsenic shown are for 2000-2001 monitoring season only. Arsenic was added to the constituent list for analytical testing for the 2000-2001 monitoring season.

For nitrate, DICE mean EMCs values were below the Caltrans highway runoff concentration of 1.1 μg/L, for both cleaned and uncleaned inlets. These mean EMCs also were well below the maximum concentration level for drinking water at 10 μg/L.

2.8.2 Analysis of DICE Water Quality Data

Comparisons were made between cleaned and uncleaned inlets using water quality EMC data collected during each year of the monitoring program, as well as the combined dataset of the 1996-1997 through 2000-2001 programs. While there were differences in the mean EMCs of indicator parameters in the storm water discharges from cleaned versus uncleaned inlets, a statistical comparison test was applied to determine whether cleaning of drain inlets resulted in significantly different mean water quality EMCs versus not cleaning the inlets. The unpaired or two-sided Student's t-tests were conducted on data from both cleaned and uncleaned inlets.

2.8.3 Analysis Methodology

2.8.3.1 Null Hypothesis

The first step in conducting the statistical comparisons was to establish the hypothesis to be tested. For the DICE Studies conducted to date, the hypothesis tested (the Null hypothesis) was that the means of the two groups (cleaned and uncleaned catchments) were the same, or

$$\mu_{\text{cleaned}} = \mu_{\text{uncleaned}}$$

The above mean values (μ) are considered "true" means because they theoretically represent the actual means of the entire cleaned and uncleaned populations. In reality, the true means of the populations can never be determined exactly because the entire population cannot be sampled; they can only be estimated based on a limited number of samples. Because they are estimates, there is uncertainty associated with the accuracy of the estimates representing the true means. Therefore, it is possible that the mean EMC estimates (the estimates based on samples) will be different between the cleaned and uncleaned groups, while at the same time the true means of the two populations are the same. The statistical comparison tests conducted in this study provide a way of evaluating whether the differences observed between the mean estimates represents an actual difference between the true means. The evaluation is based on calculation of the probability that the two true means are different given the amount of difference in the estimated (sample) means.

2.8.3.2 Statistical Significance

The second step was to establish a threshold probability for the test. This threshold is known as the level of statistical significance α. The level of statistical significance provides the false positive probability, which is the probability of concluding, based on the test results that a significant difference exists when in reality it does not exist. For purposes of the tests conducted in this study, $\alpha = 0.1$ has been established or 10% probability of generating a false positive result.

When the t-test is conducted, a probability is calculated that can be compared with statistical significance α. This probability (known as a p-value) represents the probability that the estimated EMC values could be as different as they are while at the same time the true EMC means are the same. Therefore, in order to discern a statistically significant difference, resulting p-values must be less than 0.1 (i.e., less than 10 percent probability that the mean estimates could be as different as they are and still have the same true means).

2.8.3.3 Assumptions

An important assumption in applying the comparison tests in this study was that any uncontrolled external treatment factors that could influence EMC results were either insignificant or were operating equally on both groups. This assumption was difficult to evaluate because sample groups were collected from different sets of inlets and, therefore, external factors (other than cleaning) might have affected the EMC data. Further evaluation of this assumption was conducted earlier by using exploratory analysis and by examining differences between pooled 1996-1997 and 1997-1998 data. Based on this evaluation, it was determined that the 1996-1997 and 1997-1998 data sets were similar, indicating that significant differences due to uncontrolled external factors were probably not important.

Another important assumption concerned the independence of the indicator parameters being tested. The comparison tests were conducted on the 21 different water quality indicators (six dissolved metals, six total metals, and nine water quality parameters). Testing this many parameters, the false positive probability might have become inflated. Even though α=0.1 had been set for any one individual parameter, the probability of at least one of the 21 comparison tests resulting in rejection of the Null hypothesis was equal to:

$$\alpha^* = 1 - (1 - \alpha)\ 21 = 0.89$$

or an 89% probability of rejecting the Null hypothesis based on chance alone.

This inflated false positive probability assumed that the 21 comparisons were independent (i.e., that rejection of the Null hypothesis for one parameter was unrelated to the results for any other parameter). For example, the probability that the mean EMC values for dissolved Cd being the same between the cleaned and uncleaned inlets was independent of the EMC values observed for total Zn. Under the independence assumption, the results of conducting 21 individual comparisons would have been a nearly certain probability (89%) of rejecting the Null hypothesis by chance alone and, therefore, perhaps falsely concluding that there was a statistically significant difference between cleaned and uncleaned mean EMC values.

To protect against inflated false positive probabilities, p-values were adjusted such that they were compared with an overall a*=0.1 using two similar adjustment methods, Bonferroni and Dunn-Sidak. In the Bonferroni method, the usual p-value (p) was multiplied by the number of tests (n=21) or:

$$p_{adj} = (p)\ (n)$$

In the Dunn-Sidak method, the adjustment was:

$$p_{adj} = 1 - (1 - p)^{n}$$

Both adjustment methods protected against concluding that a significant difference existed when in reality it did not.

Although most of the 21 variables are likely independent, this was not assessed analytically. Therefore, all three p-values (unadjusted, Bonferroni adjusted, and Dunn-Sidak adjusted) are provided in this report. As described above, the unadjusted p-values are representative under the assumption that all 21 variables are dependent, while the Bonferroni and Dunn-Sidak adjusted p-values are representative under the assumption that all 21 variables are independent. The same procedure was applied to the four indicator parameters that were selected to represent the litter samples.

2.8.3.4 Test for Normality

In addition to the assumptions described in Section 2.8.3.3, the assumption that the two sample distributions being compared were derived from normally distributed populations is critical to application of an appropriate comparison test method. The desired method to use for the comparisons in this study was Student's t-test, which is generally sensitive to the normality assumption. If it was determined that the sample distributions were not normally distributed, then it was necessary to transform the data to make them normal or to conduct an appropriate non-parametric (distribution insensitive) test.

Tests for normality were conducted using the Lilliefors one sample test to compare the shape and location of the sample distribution to a normal distribution. Lilliefors tests were performed for each parameter by treatment (cleaned and uncleaned) in untransformed (original) and natural log (ln) transformed scale. If both treatments had the same distribution then all subsequent comparison tests were performed on data in that scale (original or ln). For those parameters that did not follow a normal or ln normal distribution, subsequent tests were conducted using the rankings of the data. Tests performed using ranked data (non-parametric tests) were also performed when one treatment followed a normal distribution and the other a ln normal.

2.8.3.5 Equal Variance

Equal variances between cleaned and uncleaned inlet datasets is a requirement for using pooled variance t-tests. However, such equal variances were determined to not be the case for many of the indicator parameters. Therefore, it was necessary to conduct the t-tests using the separate variances technique (rather than pooled variances), which adjusts the degrees of freedom to account for unequal variances. Results of the hypothesis testing presented in this report are based on the separate variances technique.

2.8.3.6 Hypothesis Testing

Unpaired (or two-sample) Student's t-tests were performed on original, ln transformed, or ranked data (depending on the data distributions) to compare the water quality of the uncleaned and cleaned drain inlets on an individual parameter basis. For data that followed a normal or ln normal distribution, the Student's t-test was used to compare the pooled EMC values for each parameter in the cleaned inlets to the uncleaned inlets. Student's t-tests were conducted on the ranked data to compare those data that did not fit a normal or ln normal distribution.

If the probability values (p-values) resulting from the t-tests were less than 0.10, then a statistically significant difference between the cleaned and uncleaned inlets was assumed to exist. The α=0.1 level of statistical significance was for analyses performed during all five years of the monitoring project.

Three sets of p-values were calculated for each individual test. Usual p-values for t-tests conducted individually for each parameter are indicated as "p-value" and have not been adjusted for the effect of multiple parameters on the tests. These p-values were considered not to represent a true indication of significant differences between the cleaned and uncleaned data sets due to the potential for inflated false positive error rates. Therefore, adjusted p-values using two different adjustment methods (Dunn-Sidak and Bonferroni) were also calculated. The adjusted p-values take into consideration the effect of multiple parameters on the false positive error rate and are, therefore, considered better indicators of significant differences. For purposes of evaluating the test results, a significant difference between cleaned and uncleaned inlets was considered to exist for a parameter when all three p-values were less than 0.1.

2.8.4 Results of the Analysis

Two different dataset groupings were used to compare the water quality results between cleaned and uncleaned inlets:

- The individual yearly water quality dataset from all monitoring stations. The statistical test results are available in Appendix C.

- The combined 1996-1997 through 2000-2001 water quality dataset from all stations. The statistical test results are shown below in Table 2-11 and Table 2-12.

Table 2-11
Descriptive Statistics and Comparison Test Results for Analysis of the Combined 1996-1997 through 2000-2001 Metals Dataset

Category	Parameter	Cadmium (µ/L)		Chromium (µg/L)		Copper (µg/L)		Nickel (µg/L)		Lead (µg/L)		Zinc (µg/L)	
		Cleaned	Uncleaned	Cleaned	Uncleaned	Cleaned	Uncleaned	Cleaned	Uncleaned	Cleaned	Uncleaned	Cleaned	Uncleaned
Total Metals	N of cases	147	155	147	155	147	155	147	155	147	155	147	155
	Minimum	0.10	0.10	0.46	1.00	3.30	2.10	0.91	1.00	4.50	1.10	21.00	11.00
	Maximum	13.00	7.10	100.00	57.00	770.00	280.00	130.00	175.00	700.00	690.00	2400.00	1400.00
	Median	0.79	0.90	5.80	6.00	27.00	26.10	6.00	7.00	38.00	40.00	139.00	140.00
	Mean [1]	1.03	1.02	8.08	8.35	39.87	37.03	8.59	10.33	68.19	79.17	192.17	186.16
	Standard Dev	1.20	0.82	10.05	7.70	67.73	34.40	11.99	15.77	92.75	100.70	228.87	156.15
	Distribution	Neither	Neither	Neither	Neither	Neither	Ln Normal	Ln Normal	Neither	Neither	Ln Normal	Ln Normal	Neither
	Test	t-Test on Ranked Data		t-Test on Ranked Data		t-Test on Ranked Data		t-Test on Ranked Data		t-Test on Ranked Data		t-Test on Ranked Data	
	p-value	0.47		0.21		0.70		0.08		0.43		0.47	
	p-value (Dunn-Sidak)	1.00		0.99		1.00		0.82		1.00		1.00	
	p-value (Bonferroni)	1.00		1.00		1.00		1.00		1.00		1.00	
	Significant Difference	NO		NO		NO		NO		NO		NO	
Dissolved Metals	N of cases	147	155	147	155	147	155	147	155	147	155	147	155
	Minimum	0.03	0.02	0.55	0.73	1.60	1.50	0.47	0.52	0.20	0.34	9.00	2.00
	Maximum	3.10	6.10	15.00	10.00	76.00	76.00	20.00	36.00	42.00	84.00	720.00	330.00
	Median	0.40	0.40	2.00	2.10	10.00	10.00	2.00	2.00	2.10	2.74	57.00	64.00
	Mean [1]	0.45	0.49	2.28	2.46	12.44	13.12	2.91	3.47	5.24	6.86	70.91	75.37
	Standard Dev	0.40	0.56	1.43	1.30	9.93	10.08	2.57	4.19	8.51	11.47	67.72	49.58
	Distribution	Neither	Neither	Neither	Neither	Ln Normal	Ln Normal	Neither	Neither	Neither	Neither	Ln Normal	Ln Normal
	Test	t-Test on Ranked Data		t-Test on Ranked Data		t-Test on Ln Normal Data		t-Test on Ranked Data		t-Test on Ranked Data		t-Test on Ln Normal Data	
	p-value	0.49		0.08		0.51		0.34		0.15		0.29	
	p-value (Dunn-Sidak)	1.00		0.84		1.00		1.00		0.97		1.00	
	p-value (Bonferroni)	1.00		1.00		1.00		1.00		1.00		1.00	
	Significant Difference	NO		NO		NO		NO		NO		NO	

Note:

[1] Arithmetic Mean

Table 2-12
Descriptive Statistics and Comparison Test Results for Analysis of the Combined 1996-1997 through 2000-2001 Water Quality Parameter Dataset

Category	Parameter	Hardness (mg/L)		Total-N (mg/L)		Dissolved-P (mg/L)		Total-P (mg/L)	
		Cleaned	Uncleaned	Cleaned	Uncleaned	Cleaned	Uncleaned	Cleaned	Uncleaned
Water Quality	N of cases	147	154	100	104	134	151	145	155
	Minimum	3.30	10.00	0.19	0.24	0.02	0.01	0.01	0.02
	Maximum	365.00	448.00	4.20	3.30	0.81	0.74	1.20	1.00
	Median	37.00	44.00	0.77	0.91	0.10	0.10	0.17	0.20
	Mean [1]	47.50	60.87	1.04	1.10	0.12	0.14	0.21	0.24
	Standard Dev	40.86	57.16	0.84	0.68	0.10	0.13	0.20	0.20
	Distribution	Ln Normal	Neither	Ln Normal	Neither	Neither	Neither	Neither	Neither
	Test	t-Test on Ranked Data		t-Test on Ranked Data		t-Test on Ranked Data		t-Test on Ranked Data	
	p-value	0.01		0.10		0.41		0.13	
	p-value (Dunn-Sidak)	0.21		0.89		1.00		0.94	
	p-value (Bonferroni)	0.24		1.00		1.00		1.00	
	Significant Difference	NO		NO		NO		NO	

Category	Parameter	Total Suspended Solids (mg/L)		Total Kjeldahl Nitrogen (mg/L)		Total Organic Carbon (mg/L)		Total Volatile Solids (mg/L)		Specific Conductivity (uhms/cm2)	
		Cleaned	Uncleaned	Cleaned	Uncleaned	Cleaned	Uncleaned	Cleaned	Uncleaned	Cleaned	Uncleaned
Water Quality	N of cases	145	155	145	155	146	155	116	123	140	154
	Minimum	10.00	9.00	0.10	0.10	0.60	1.60	1.00	1.00	18.00	28.10
	Maximum	983.00	1230.00	57.00	11.30	51.00	50.60	274.00	136.00	458.00	923.00
	Median	56.00	70.00	1.10	1.20	7.50	8.30	36.50	42.00	70.90	84.70
	Mean [1]	97.12	121.72	1.85	1.52	9.85	10.83	45.28	48.13	95.88	124.11
	Standard Dev	119.67	161.82	4.74	1.35	8.15	8.17	39.03	28.65	72.49	125.59
	Distribution	Neither	Ln Normal	Neither	Neither	Ln Normal	Ln Normal	Neither	Neither	Ln Normal	Neither
	Test	t-Test on Ranked Data		t-Test on Ranked Data		t-Test on Ln Normal Data		t-Test on Ranked Data		t-Test on Ranked Data	
	p-value	0.10		0.99		0.06		0.07		0.01	
	p-value (Dunn-Sidak)	0.88		1.00		0.73		0.78		0.22	
	p-value (Bonferroni)	1.00		1.00		1.00		1.00		0.25	
	Significant Difference	NO		NO		NO		NO		NO	

Note:
[1] Arithmetic Mean

Although statistically discernable differences between the cleaned and uncleaned inlets were not apparent for any of the individual parameters, four of the 21 parameters had relatively higher mean EMCs in the cleaned inlets versus 11 parameters with relatively higher mean EMCs in the uncleaned inlets. There was no difference between the means for the remaining six parameters. Assuming no difference between cleaned and uncleaned mean EMCs, the number of cases would be expected to be about the same, i.e., an even distribution with 10 or 11 cases each. Such an even distribution would correspond to a one-sided probability of 0.5 (50 percent). For example, there is a 50 percent probability that cleaned mean EMCs will be higher than uncleaned mean EMCs. The probability of observing four or less cases out of 21 total, where the cleaned mean exceeded the uncleaned mean is only about 0.03 (3 percent). Therefore, the results suggest that when viewed in total, the uncleaned inlets may have slightly higher mean EMCs than the cleaned inlets. However, none of the 11 cases where higher mean EMCs were observed in uncleaned inlets correspond with statistically significant differences based on the t-test. This is because the differences are not large enough to be discernable statistically using the t-test and the amount of data available.

2.8.5 Power Analysis

An additional statistical analysis was performed to evaluate the minimum detectable relative percent differences (RPDs) between cleaned and uncleaned Event Mean Concentrations (EMCs), and to estimate the number of samples necessary to attain mean RPDs of 10, 25, 50 and 75 percent. The result of this analysis is referred to as a "power analysis". A data objective of the DICE Study was established to obtain sufficient data to be able to discern a 25% RPD between EMCs from cleaned versus uncleaned catchments.

Table 2-13 summarizes the observed RPDs, results of the t-tests, and minimum detectable RPDs. All the results are for the pooled 1996-1997 through 2000-2001 data (i.e., all data collected to date for the DICE Study). The observed RPDs (column labeled "RPD Observed") represent the actual or observed differences between the means of the cleaned and uncleaned groups. The results of the t-tests are summarized in the column "Statistical Analysis Results", where "No" indicates that the observed RPD was not statistically discernable and "Yes" indicates that it was discernable. It should be noted that these results are based on $\alpha = 0.1/21$, i.e., parameters are independent. The minimum detectable RPDs (last two columns) corresponds to the assumption of dependence amongst the parameters ($\alpha = 0.1$) and independence ($\alpha = 0.1/21$).

Table 2-13
Caltrans DICE - Summary of RPD and Power for Pooled 1996-2001 Data

Parameter	RPD Observed[1]	Statistical Analysis Results[2]	Min detectable RPD[3]	
			α= 0.1	Α= 0.1/21
Total Cadmium	5%	NO	17.2%	25.5%
Total Chromium	9%	NO	17.3%	25.7%
Total Copper	3%	NO	17.2%	25.6%
Total Nickel	12%	NO	17.1%	25.5%
Total Lead	5%	NO	17.0%	25.3%
Total Zinc	5%	NO	16.9%	25.2%
Dissolved Cadmium	5%	NO	16.5%	24.5%
Dissolved Chromium	12%	NO	18.0%	26.8%
Dissolved Copper	2%	NO	10.8%	13.2%
Dissolved Nickel	7%	NO	19.0%	28.3%
Dissolved Lead	10%	NO	18.3%	27.2%
Dissolved Zinc	2%	NO	5.2%	7.7%
Hardness	17%	NO	16.8%	24.9%
Total-N	14%	NO	20.7%	30.9%
Dissolved-P	8%	NO	24.5%	36.4%
Total-P	11%	NO	18.1%	26.9%
Specific Conductivity	17%	NO	17.2%	25.5%
Total Suspended Solids	11%	NO	17.1%	25.3%
Total Kjeldahl Nitrogen	0%	NO	18.7%	27.8%
Total Organic Carbon	8%	NO	10.0%	14.9%
Total Volatile Solids	14%	NO	19.4%	28.8%

Note:

1 Relative Percent Difference between the means of the cleaned and uncleaned drain inlets.
2 "NO" indicates that the observed RPD was not statistically significant. "YES" indicates a statistically significant difference based on power of the t-test of 0.5 and the alpha = 0.1 /21 level.
3 Applies to Power = 0.8.

Power curves were constructed to evaluate whether the current data are sufficient to discern different RPDs. A summary of the power curve analyses is provided in Table 2-14 for power = 0.8, various RPDs (10, 25, 50 and 75 percent), and the two alpha levels (α = 0.1 and α = 0.1/21). The numbers represent the number of additional samples required to discern the indicated RPD.

Table 2-14
Caltrans DICE - Summary of Power Analysis Results for Pooled 1996-2001 Data

Parameter	Additional Samples Required to Detect RPD in Means. [1]							
	RPD = 10		RPD = 25		RPD = 50		RPD = 75	
	α=0.1	α=0.1/21	α=0.1	α=0.1/21	α=0.1	α=0.1/21	α=0.1	α=0.1/21
Total Cadmium	284	790	0	6	0	0	0	0
Total Chromium	290	801	0	8	0	0	0	0
Total Copper	287	796	0	7	0	0	0	0
Total Nickel	283	786	0	6	0	0	0	0
Total Lead	277	774	0	4	0	0	0	0
Total Zinc	272	764	0	2	0	0	0	0
Dissolved Cadmium	252	720	0	0	0	0	0	0
Dissolved Chromium	328	886	0	42	0	0	0	0
Dissolved Copper	0	107	0	0	0	0	0	0
Dissolved Nickel	383	1005	0	40	0	0	0	0
Dissolved Lead	344	921	0	17	0	0	0	0
Dissolved Zinc	0	0	0	0	0	0	0	0
Hardness	265	749	0	0	0	0	0	0
Total-N	326	825	0	51	0	0	0	0
Dissolved-P	665	1601	0	147	0	0	0	0
Total-P	327	880	0	22	0	0	0	0
Specific Conductivity	270	750	0	6	0	0	0	0
Total Suspended Solids	275	767	0	0	0	0	0	0
Total Kjeldahl Nitrogen	360	953	0	34	0	0	0	0
Total Organic Carbon	1	174	0	0	0	0	0	0
Total Volatile Solids	315	822	0	37	0	0	0	0

Note:
[1] Calculated from Power Curves for Power = 0.8.

Table 2-14 indicates that no additional samples are required to distinguish an RPD of 25 percent for any of the parameters, assuming the parameters are dependent (alpha =0.1). Assuming sample independence (α = 0.1/21), an RPD of 25 percent can be distinguished for six of the 21 parameters (dissolved Cadmium, dissolved Copper, dissolved Zinc, hardness, total suspended solids, and total organic carbon). For seven other parameters, an RPD of 25 percent would require less than 10 additional samples (total Cadmium, total Chromium, total Copper, total Nickel, total Lead, total Zinc, specific conductivity). The remaining eight parameters would require between 17 and 147 additional samples in order to distinguish an RPD of 25 percent under the independence assumption. For most parameters, an RPD of 10 percent would require at least 200 additional samples, assuming dependence, and at least 700 additional samples, assuming independence. In three cases (dissolved copper, dissolved zinc, and total organic carbon), an RPD of 10% has been achieved, assuming dependence.

Results of the power analysis performed at the end of the study indicate that no additional samples are required to distinguish a Relative Percent Difference (RPD) of 25 percent for all of the water quality parameters. An RPD of 25 percent can currently be distinguished for six of the 21 water quality parameters, and for seven other parameters, less than 10 additional samples would be required. For the remaining eight parameters, between 17 and 147 additional samples would be required to achieve an RPD of 25 percent, under the complete independence assumption.

2.9 Litter

New to the 2000-2001 DICE Study was the introduction of the litter monitoring and collection component. With recent regulatory action concerning litter, Caltrans decided to add a litter component to the DICE Study for 2000-2001. The data can be used to evaluate the efficacy of the drain inlet cleaning to reduce the quantity of litter that discharges from the highway drainage system. In addition, the data from the DICE Study complements litter data from other Caltrans studies and generally includes larger catchments than had been previously monitored. Each site, in addition to the flow meter, automatic sampler, and rain gauge, was equipped with one or more mesh bags to collect all the litter and vegetation that was discharged from the outfall. The mesh bags had one-quarter inch openings.

The laboratory analysis involved separating the litter and vegetation components from any sediment. This separated material was identified as “gross pollutants”. The total mass and volume of the gross pollutants were then measured while the material was still wet. The gross pollutants were then separated into the litter and vegetation components and their individual wet masses and volumes measured. Finally, the litter component was allowed to dry and its dry mass and volume measured. The cumulative season summary of litter data is shown in Table 2-15. During the 2000-2001 seasons, the total wet mass of gross pollutants removed from the catchments ranged from 368 kilograms at the largest site, Site 26, to 32 kilograms at the smallest site, Site 21.

Table 2-15
Storm Season Litter Totals

Site	Cleaned / Uncleaned	Drainage Area (hectares)	Gross Pollutants Mass (kg)	Gross Pollutants volume (m^3)	Wet Vegetation Mass (kg)	Wet Vegetation volume (m^3)	Wet Litter Mass (kg)	Wet Litter volume (m^3)	Dry Litter Mass (kg)	Dry Litter volume (m^3)	Dry Litter Mass per Drainage Area (kg/hectare)	Dry Litter Volume per Drainage Area (m^3/hectare)
21	Cleaned	0.49	32.44	0.10	24.47	0.06	7.37	0.04	3.60	0.04	7.35	0.08
22	Cleaned	0.89	206.58	0.49	161.32	0.26	42.15	0.23	29.41	0.25	33.04	0.28
23	Uncleaned	2.83	197.97	0.47	172.47	0.37	22.82	0.11	12.92	0.11	4.57	0.04
24	Uncleaned	2.91	266.72	0.55	189.67	0.29	74.49	0.26	34.95	0.26	12.01	0.09
26	Cleaned	12.59	368.25	0.73	327.46	0.53	36.09	0.18	20.92	0.20	1.66	0.02
27	Uncleaned	1.46	193.63	0.38	178.15	0.33	12.54	0.05	7.26	0.05	4.97	0.03
28	Uncleaned	2.75	167.40	0.25	147.81	0.18	18.00	0.07	12.33	0.06	4.48	0.02
29	Cleaned	0.81	236.23	0.24	222.16	0.18	11.11	0.06	6.32	0.05	7.80	0.06

2.9.1 Litter Observations

The 2000-2001 litter monitoring included the following observations:

- The majority of the gross pollutants by both wet mass and volume are vegetation. From 70 to 90 percent of the gross pollutant wet mass is vegetation and 50 to 90 percent of the wet volume is vegetation.

- From 30 to 50 percent of the wet mass of litter appears to be water when the wet masses are compared to the dry masses.

- The volume of litter changes relatively little after it is dried.

- Site 22 by far had the highest dry litter mass per hectare of all sites. Five of the sites fell within the range of 5 to 12 kg of dry litter per hectare, whereas Site 22 had over 33 kg of dry litter per hectare. Site 26 had the lowest ratio at 1.66 kg of dry litter per hectare. Site 26 has the largest catchment area and is located in a rural section of District 7.

- No obvious trends can be seen when data from the cleaned and uncleaned catchments is compared. On a per hectare basis, the cleaned catchments had both the highest and lowest dry litter amounts. Unit area dry litter amounts were higher in the cleaned catchments.

- Material that collected in the bags in between rainfall/runoff events represented a small percentage of the season totals. No material accumulated in the bags at Sites 21 and 22 between storm events. At Sites 24, 26, 27, and 29, the percentage ranged from one to five percent. At Sites 23 and 28, the percentage was 20 and 10 percent, respectively. The higher percentage at these two sites is attributed to the occurrence of irrigation runoff. The majority of the material accumulated between storm events was comprised of vegetation, with percentages similar to the season totals.

2.9.2 Analysis of DICE Litter Data

A similar statistical analysis was performed on the 2000-2001 DICE litter quantity data for uncleaned and cleaned inlets as was conducted on the 1996-1997 to 2000-2001 combined water quality data. Cleaning the drain inlets was found to have very little impact on the quantity of litter and vegetation in the runoff discharged from the Caltrans highway system in District 7, based on statistical analysis of the limited data collected in 2000-2001. As shown in Table 2-16, no statistical difference was found in the mean normalized values for the four litter parameters (gross pollutants, vegetation, wet litter, and dry litter) between catchments where cleaning was performed and those where cleaning was not performed for any of the four parameters.

Table 2-16
Descriptive Statistics and Comparison Test Results for Analysis of the 2000-2001 Litter Dataset

Category	Parameter	Dry Litter (g/m^3)		Wet Litter (g/m^3)		Wet Vegetation (g/m^3)		Gross Pollutants (g/m^3)	
		Cleaned	Uncleaned	Cleaned	Uncleaned	Cleaned	Uncleaned	Cleaned	Uncleaned
2000-2001 Data									
	N of cases	37	36	37	36	37	36	37	36
	Minimum	0.12	0.40	0.22	0.93	0.69	1.71	1.12	3.42
	Maximum	76.74	33.34	151.55	41.27	520.80	540.98	540.05	593.08
	Median	5.02	3.95	9.71	7.27	40.88	67.21	52.80	81.14
	Mean [1]	11.69	8.63	20.81	14.06	93.59	105.68	116.26	121.31
	Standard Dev	18.29	8.54	34.02	13.02	121.85	115.24	143.35	125.41
	Distribution	Ln Normal	Ln Normal	Ln Normal	Ln Normal	Ln Normal	Ln Normal	Ln Normal	Ln Normal
	Test	t-Test on Ln Normal Data		t-Test on Ln Normal Data		t-Test on Ln Normal Data		t-Test on Ln Normal Data	
	p-value	0.39		0.55		0.13		0.18	
	p-value (Dunn-Sidak)	0.86		0.96		0.44		0.54	
	p-value (Bonferroni)	1.00		1.00		0.53		0.71	
	Significant Difference	NO		NO		NO		NO	

***Notes*:**
[1] Arithmetic Mean

Section 3
Related Program and Studies

The Solids Transport and Deposition Study (STDS) was conducted for a one year period from March 1998 through March 1999, during which monitoring data was collected for analysis. The STDS aimed to evaluate if targeted cleaning for specific inlets could be established based on monitoring data.

The STDS Final Report was completed in June 1999. The STDS data was further evaluated in an STDS Addendum, Spring 2000. Section 3.1 summarizes the results of the STDS.

The District 7 enhanced Drain Inlet Inspection and Cleaning (DIIC) Program has been ongoing since 1995. In conjunction with the cleaning activities, a substantial body of data has been collected under this program. Section 3.2 summarizes the results of the program conducted through Fall 2001. At the writing of this report, inspection and cleaning data was not available for enhanced cleaning in Fall 2002.

3.1 Solids Transport and Deposition Study (STDS)

The overall objective of the Solids Transport and Deposition Study (STDS) was to characterize the rates and patterns of solid material transfer to and the collection within the storm water drain inlets located along Caltrans highway facilities. Specifically, the data collected was used to determine if certain distinguishable site characteristics or factors affected the transport and deposition of sediment, metals, vegetation, litter, and petroleum hydrocarbons to drain inlets. This study involved an intensive year of monitoring at selected drain inlets located within Caltrans District 7. Figure 3-1 identifies the locations of the monitored drain inlets.

3.1.1 Study Design and Approach

The STDS was based on a factorial design approach. This approach, as applied to the STDS, sought to relate solids volume and mass accumulation characteristics in Caltrans District 7 drain inlets to specific site characteristic factors. A factorial study design was used in order to draw statistical inferences about the effect individual site characteristic factors had on a response, such as mass accumulation of solids or the concentration of selected constituents in the sediments. This type of design is useful when more than one characteristic might influence the response. For the STDS, four primary site characteristic factors were evaluated. These four factors are listed in this section, along with a description of how they were applied to the STDS.

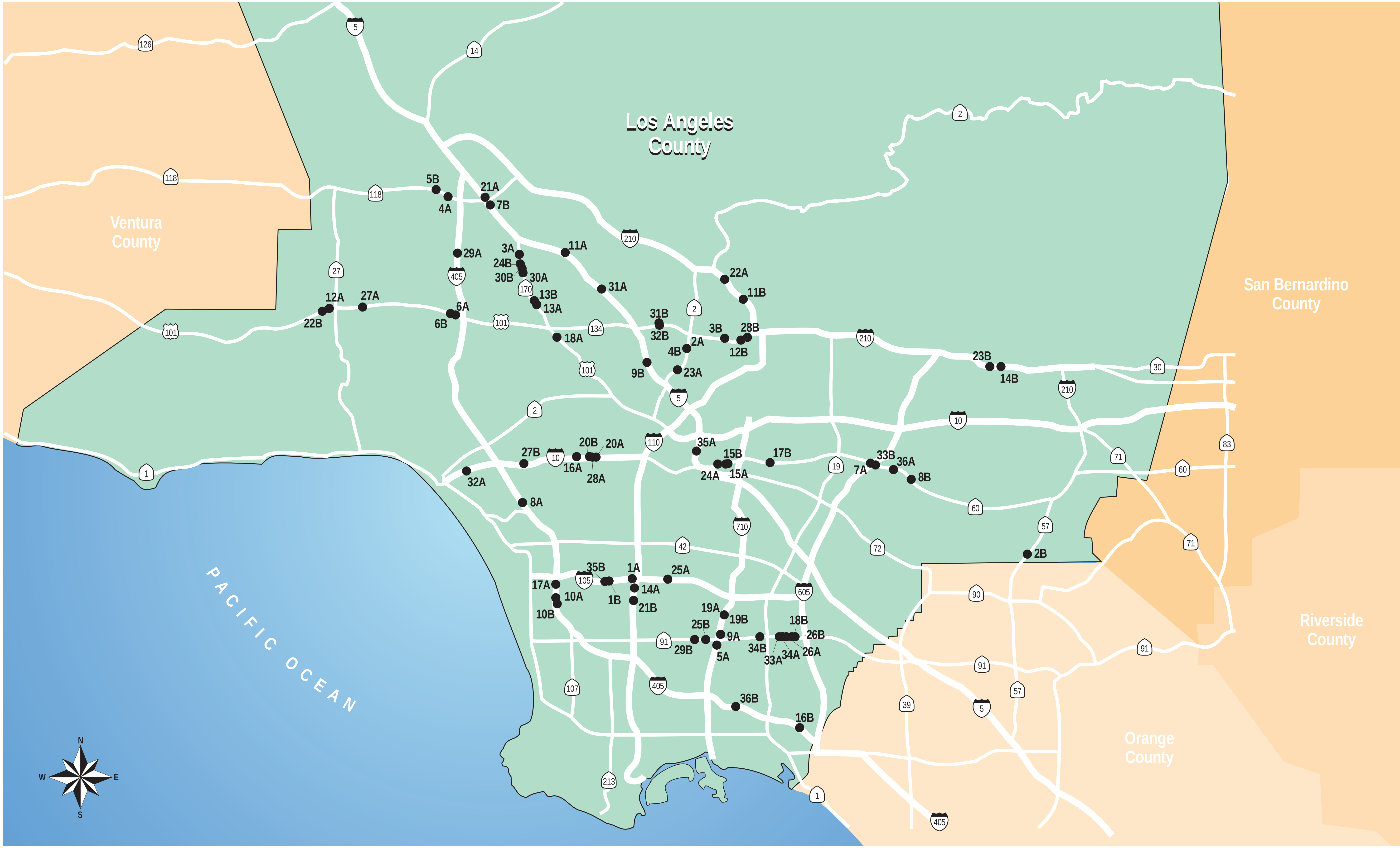


Figure 3-1
California Department of Transportation
Solids Transport and Deposition Study
Location of Monitoring Sites

- **Erosion Control/Sediment Loading Potential.** This factor was selected to evaluate two general contrasting conditions (i.e., factor levels): whether or not the right-of-way area that was adjacent to the study drain inlet site was vegetated or non-vegetated.

- **Litter Management.** Litter Management was also selected to evaluate two general factor contrasting levels: low and high levels of litter along the roadway associated with the study inlet. Relative litter levels were based on a surrogate factor, Average Daily Traffic (ADT) volumes for highways in District 7. The use of ADT was considered a reasonable option to rank litter levels, because other studies have fairly well correlated the levels of litter along highway segments with ADT volumes. However, it should be noted that the correlation between high levels of litter along the highway right-of-way and the accumulation of litter in storm water drainage structures has not been demonstrated.

- **Land Use/Toxic Loading Potential.** This factor was selected to evaluate the toxic loading potential of three different urban land use categories in the vicinity of the roadway: low density residential, major commercial, and heavy industrial. However, a suitable set of sites with predominant surrounding single land use categories were not identified. Therefore, the surrounding percent impervious area was used as a surrogate to characterize the mix of land uses within a 300-meter radius of each drain inlet site. The mix of land uses was applied to four levels of imperviousness: low, medium low, medium high, and high.

- **Roadway Design.** This fourth factor was selected to evaluate three general conditions that reflected the physical configuration of the roadway at the drain inlet site. These conditions included cut slope, at-grade/fill, and the presence of sound walls.

The total number of unique combinations amongst the four factors, and each factor's associated conditions or levels, was referred to as the "number of treatments." For the STDS, the number of treatments equaled 36. Two replicate sites representing each of the 36 treatments were used in the study. Thus, a total of 72 sites (individual inlets) were selected for monitoring. The selection process reviewed about 13,600 drain inlets and selected the final 72 based on physical site characteristics that matched the four factors and were limited to those drain inlets that were located along the right shoulder, provided adequate crew safety, and avoided construction zone impacts.

3.1.2 Field Monitoring

The monitoring program involved inspecting each site once every two weeks for a year, for a total of 26 inspection visits. The two-week period during which each site was inspected was designated as a sampling "round" and each round was numbered sequentially. The accumulated material was measured in terms of compacted and uncompacted volumes. The uncompacted volume was determined from measuring the depth of uncompacted solids by holding a measuring rod just over the surface of the material. The compacted volume was determined by depth of solids when the full weight of the measuring rod was allowed to rest on the solids. Site conditions were also documented during each inspection.

During every other round (once every four weeks), samples of the accumulated solids were collected and the relative composition of the solids was estimated in terms of litter, vegetation, and sediment. The collected samples were sent to laboratories for analysis of metals (lead, copper, chromium, and zinc), organics (benzene, toluene, ethylbenzene, xylenes [BTEX]; and petroleum products [gasoline, diesel, jet fuel, kerosene, stoddard solvent]), and slurry Eh and pH.

For both the measurements of accumulated volume and the withdrawal of samples for analyses, care was taken to minimize disturbance of the material in the inlet. This was done so as to not interfere with “typical” deposition and transport processes during the study.

In addition, data was compiled on various external factors that might also influence the deposition and transport of solids along highways. These external factors included wind and rainfall, road slope and alignment, right-of-way (embankment) slope and width, proximity of overpasses, and the presence of barriers. Rainfall and wind data were obtained from a series of meteorological stations located within the study area. The data was assigned to each of the 72 STDS drain inlet by a weighting factor that used the distance from the meteorological stations to a particular drain inlet.

An estimated density was required to convert the volumes of sediment to a mass. This density was based on the results of the Bulk Density Core Method performed on 10 archived sediment samples collected during STDS. The results were only applied to sediment and did not include litter or vegetation. The calculated value represented a "best estimate" of sediment density for the STDS inlets and was applied to all calculations of sediment mass.

All the data collected during the STDS was compiled into a Microsoft Access 97© database. The database is contained within an application that is designed to provide access to all the information including site characteristics, solids accumulation data, analytical data, field status reports, summary tables and figures, statistical analyses results, photographs taken at each site on a monthly basis, quality control data, and meteorological data. The database is provided on a CD with the STDS report and can be installed on a personal computer.

3.1.3 Field Data and Analytical Results

All 72 inlets included in the STDS accumulated solids throughout the 12-month study period. As shown in Figure 3-2, the compacted volume of accumulated solids increased during the first 15 rounds, peaking during Rounds 15 and 16 (October 1998) at a mean value per inlet of 0.092 m^3 with standard deviation of 0.112 m^3 and a minimum/maximum range of 0.003 to 0.686 m^3. After Round 16, the mean compacted volume per inlet remained relatively constant, fluctuating between 0.07 to .09 m^3.

During the first 16 rounds, the mean solids accumulation rate in the STDS inlets ranged between 0.0004 to 0.0007 m^3/day per inlet, a relatively constant rate. However the minimum rates varied between 0 and –0.005 m^3/day and the maximum rates ranged from .003 to 0.007 m^3/day. After Round 16, the mean accumulation rate varied considerably, ranging between –0.0012 to .0005 m^3/day. The change in the accumulation patterns after Round 16 coincided with the start of the wet season in southern California.

Based on qualitative field observations, the average solids composition was comprised of 20 percent litter, 55 percent vegetation, and 25 percent sediment. The accumulation of each component followed the same general patterns as found with their combined volume and rate.

Each of the STDS drain inlets were paired with a second inlet that was selected to include the same study design factors. The degree of similarity (in terms of solids volumes) between an associated replicate pair was defined by a similarity index (SI) number. The average SI value calculated for the 36 replicate pairs was 0.6 out of a possible score of 1.0; a score of 1.0 was achievable if the volumes tracked exactly. This value of 0.6 suggested factors other than the four study design factors might impact solids accumulation at the inlets.

Detectable total metals concentrations for chromium (Cr), copper (Cu), lead (Pb), and zinc (Zn) were found in the majority of the analyzed STDS sediments samples. The estimated mass accumulation for all four metals closely followed the accumulation trends found in the solids volume.

Analysis of the sediment samples showed that many of the targeted organic parameters (e.g., petroleum products, BTEX) were not detected at concentrations above the laboratory's reporting limits. The California Waste Extraction Test and the Toxicity Characteristic Leaching Procedure analyses indicated there were potentially leachable fractions of some metals present in the sediments.

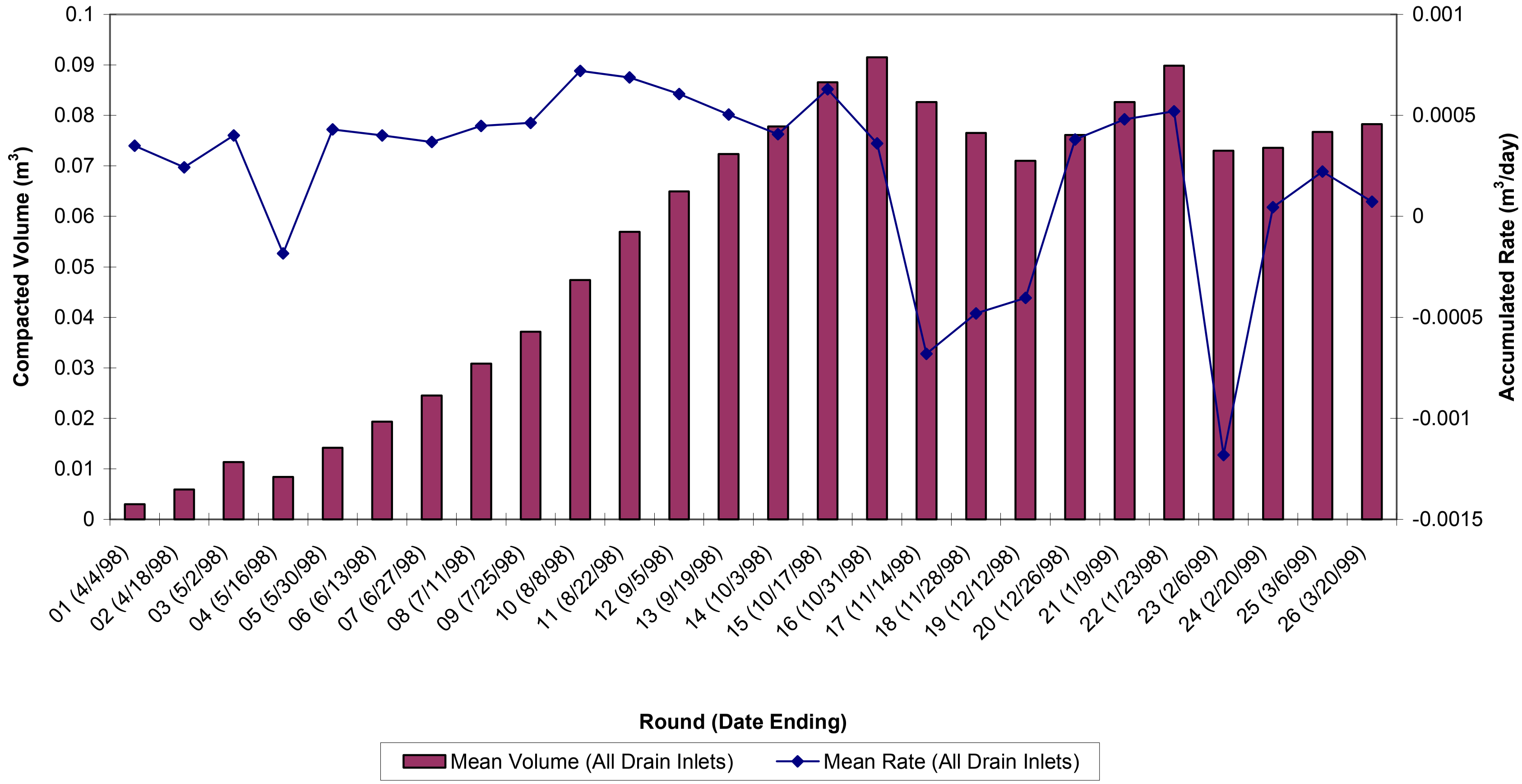


Figure 3-2
Average Solids Accumulation from All Rounds:
All Solids

3.1.4 Data Analyses by ANOVA

Analysis of variance (ANOVA) was the primary statistical method applied to identify the individual site characteristic factors that controlled the transport and deposition of solids to the 72 STDS drain inlets. The ANOVA method was selected because the factorial design of the STDS resulted in the natural grouping of the data into a large number of categories.

The numbers of possible data groups were a function of the four STDS design factors, the number of categories within each factor (referred to as factor levels), and the resulting combinations of the various factor levels (referred to as interactions). The grouping of data into one of the main factor levels (e.g., High and Low ADT) was referred to as a main effect. The grouping of data into one of the combinations of factor levels (e.g., Vegetated/High ADT, Non-vegetated/High ADT, Vegetated/Low ADT and Non-vegetated/Low ADT) was referred to as an interaction effect. In the STDS design there were four main factors representing each of the four study design characteristics, six second-level interactions that combined two of the four design factors, four third-level interactions that combined three of the four factors, and one fourth-level interaction that combined all four factors, for a total of 15 groups.

The ANOVA analyses were conducted under two separate study conditions. The first condition included the entire study period, Round 1 through Round 26. The second condition included only the interval between Round 5 and Round 15 (June through September 1998). The Round 5 to Round 15 interval was selected because solids accumulation rates were relatively constant throughout this period. In addition, cumulative rainfall was insignificant between Round 5 and Round 15 and, therefore, this interval might have been representative of dry deposition conditions.

For the full period analyses, cumulative rainfall and wind speed data were included in the ANOVA as co-dependent variables (covariates). Covariates might be thought of as "background variables" that were related to the dependent variables (e.g., solids volume). Both covariates (rainfall and wind speed) were considered "cumulative" because they represented the sums of rainfall and wind speed over the intervals between measurement and/or sampling dates.

ANOVA analyses were conducted for two categories of dependent variables:

- Solid Volumes Accumulation (cubic feet).

- Metals Mass Accumulation (grams).

- For solids volumes, compacted solids volume measurements collected on a bi-weekly basis were used in the analyses. For metals masses, concentration data collected on a monthly basis were used.

The factorial ANOVA used in this study was a type of analysis designed to test the equivalence of means across two or more data groups (e.g., solids accumulation within drain inlets where the adjacent right-of-way was vegetated or non-vegetated). The data groups corresponded to the study design factors and their associated factor levels (commonly referred to as treatments). Therefore, ANOVA was an inferential test and was subject to certain assumptions regarding the distributions of data within the groups. If the data did not meet these assumptions, then the resulting probabilities for the ANOVA statistics might be suspect.

In general, there were four primary assumptions: 1) equal variance; 2) symmetry; 3) independence; and 4) outliers. A series of evaluations was performed to define the relative importance of each assumption to the ANOVA analysis and whether the assumptions had been met. In addition, methods were applied to either eliminate or minimize the impact of violations of the assumptions where appropriate.

ANOVA determined whether group means differed based on an established statistical significance. For the STDS, a pre-established level of statistical significance was not established. Instead, all 15 effect groups (four main factors and eleven combinations of factors) were analyzed, and those groups that resulted in an ANOVA p-value less than 0.2 were evaluated further.

If the ANOVA p-value was less than 0.2, contrast testing was performed on all possible pairs within the effect grouping. For example the main factor for ADT had only one pair to test, High and Low ADT. Whereas, the combination of the vegetation factor and the ADT factor had four pairs to test, Vegetated/High ADT, Non-vegetated/High ADT, Vegetated/Low ADT, and Non-vegetated/Low ADT. Results of the contrast testing were also provided in terms of p-values. Such p-values indicated the probability that the means of the two groups tested were really different. If the p-value for the contrast was less than 0.2, this result was used to define a significant difference in the accumulation of solids volume or metal masses.

It should be noted that although 0.2 is being used as a "cutoff" p-value level, it should not be considered as necessarily representative of a statistically significant result, i.e., it should not be considered as the level of statistical significance for purposes of identifying statistically significant effects, since a 20 percent probability is usually considered too high to be statistically significant. The p-value = 0.2 criterion was only selected as a means of presenting the results of the analysis.

3.1.5 Influence of the Four Study Design Factors

The results of the ANOVA analyses indicated a few of the factors or combinations of the factors did influence the accumulation of solids volumes and metals mass at the 72 STDS drain inlets. However, the analyses indicated that the majority of the 15 groups of factors and combination of factors did not have an influence.

Differences in solids accumulation most commonly occurred as a result of differences in roadway configurations. When tested alone, the accumulation of solids volumes and all four metal masses were higher at the STDS inlets with cut sections than inlets that had either at-grade or fill roadway sections. This trend occurred during both the full and dry-weather test conditions. The ANOVA results with combinations that included the road configuration factor (vegetation*road configuration, imperviousness*road configuration, and ADT*imperviousness *road configuration) often indicated lead mass accumulated at a higher rate at the inlets with cut sections. Several of the tests for copper and chromium showed this same trend.

The ANOVA test found inlets with high ADT accumulated more copper and chromium than sites with low ADT. The same was true for combinations of vegetation and ADT. Inlets at non-vegetated sites and high ADT accumulated higher amounts of these metals than inlets at sites with vegetation and/or low ADT.

The remaining eight effect sources did not identify a difference in the accumulation of solids or metals among the 72 STDS inlets. These sources included:

- vegetation,
- vegetation × imperviousness,
- ADT × imperviousness,
- ADT × road configuration,
- vegetation × ADT × imperviousness,
- vegetation × ADT × road configuration,
- vegetation × imperviousness × road configuration, and
- vegetation × ADT × imperviousness × road configuration.

The ANOVA analyses indicated the four study design factors had little impact on the accumulation of solids or metals at the inlets with sound walls. Only one ANOVA test found a difference between the accumulation of lead mass at inlets with medium low imperviousness versus inlets with low imperviousness.

3.1.6 Influence of Other External Factors

ANOVA results indicated that the four study design factors selected for the STDS did not always account for the majority of the variance in the two dependent variables (solids volume accumulation and metals mass accumulation). Other factors not included in the study design were responsible for a portion of the variance as well.

These other (or external) factors had not been identified; however, additional data were collected at the 72 drain inlets to attempt to identify certain suspected external factors. These data included:

- Road slope,
- Road alignment,
- Embankment slope,
- Embankment angle,
- Embankment length,
- Distance to nearest overpass, and
- Distance to nearest ramp/gore point.

Statistical analyses of these external factors using ANOVA, principal component analysis, and cluster analysis were conducted to determine their possible importance.

External factors that might be contributing to solids volumes accumulation (in addition to the study design factors) were first investigated using ANOVA. This investigation indicated that the embankment slope might be an important factor for solids volumes accumulation, which corresponds with the results obtained for the road configuration study design factor. Considerable contributions to the solids accumulation at STDS inlets associated with the other potential external factors were not indicated by the ANOVA.

The Principal Component Analysis (PCA) was a second analysis applied to try to define the importance of external factors in solids accumulation at the STDS inlets. It is an analysis designed to study the correlations of a large number of variables. Nine variables were selected for analysis using PCA. The results of this analysis indicated that most of the variance (about 73 percent) within the STDS data was accounted for by four components composed of various combinations of the nine variables. Five of these variables were related to the four study design factors. For example, embankment slope and embankment length are related to the road configuration factor. As expected, these four components were seen to generally correspond with the four study design factors.

Cluster analyses was used to represent the similarities in solids accumulation among the 72 STDS drain inlets during the study. Results of the cluster analyses indicated that although some replicate inlet pairs did group together (i.e., had similar solids volumes accumulation), the overall groupings did not appear to follow any recognizable pattern. This result suggests indirectly that the four study design factors do not entirely control the accumulation of solids and metals mass in the 72 STDS drain inlets.

3.1.7 Additional Analysis and Observations

Additional analyses were conducted to extract further information from the data collected during the study, as well as data collected under related studies conducted in District 7. The purpose was to present the results of the additional analyses and provide recommendations to Caltrans that will assist in designing cleaning program modifications.

Presented below is a summary of the results of the additional analyses and observations.

3.1.7.1 Solids Transports Mechanisms.

The STDS successfully verified that solids accumulation in the 72 study drain inlets primarily occurred during dry weather periods rather than wet weather periods. The data collected during the STDS demonstrated that solids accumulated in drain inlets during dry weather periods. This important conclusion was supported by field personnel observations regarding the mechanism by which solids entered the drain inlets. Field observations verified that solids were mobilized by vehicle-induced wind turbulence and that the mobilized solids were then falling into the drain inlets by gravity.

3.1.7.2 Right Shoulder Representativeness.

The 72 drain inlets included in the STDS were all located on the right shoulders of District 7 freeways. This was necessary due to safety concerns for both field personnel and the public during the field investigation. However, the exclusive use of right shoulder inlets may not be representative of the total population of inlets (e.g., left shoulder and median inlets). Statistical comparison tests were conducted in order to assess whether the factors affecting solids accumulation in right shoulder inlets correspond with the same factors affecting solids accumulation in left shoulder (or median) inlets. An initial evaluation was conducted on the 23,000 inlets included in the Drain Inlet Inspection and Cleaning (DIIC) study (see Section 3.2). The DIIC database included solids measurements once per year for 1997, 1998, and 1999. Results of this initial evaluation indicated that on a "per inlet" basis a statistically significant difference exists between the mean solids volumes in right versus left (and other) inlets. However, the results are not consistent year to year and the relative percent difference between left and right shoulder is small. During the year over the three-year period 1997-1999, the mean solids volumes in left shoulder inlets was only 1% to 6% greater than the mean volume in right shoulder inlets.

3.1.7.3 Cut-Slope vs. At-Grade Analyses.

Statistical tests were conducted on the detailed DIIC data to determine whether a significant difference in solids volume existed between cut slope and at-grade/fill drain inlets. The detailed DIIC data included approximately 4,400 drain inlets that were classified as either cut slope, fill, or at-grade road configuration. The analysis did not indicate a statistically significant difference between the cut slope and at-grade/fill inlets. The results of this testing tend to dispute the conclusion of the STDS that cut-slope inlets accumulate significantly more solids than at-grade/fill inlets. These results indicate that targeting drain inlet cleaning on cut-slope inlets may not actually result in significant higher removal of solids volumes.

3.2 Drain Inlet Inspection and Cleaning (DIIC) Program

As noted in Section 1, Caltrans has been conducting a drain inlet cleaning program in District 7 since 1995 and a combined inspection and cleaning program since 1996. The nature and extent of the cleaning program has been redefined on a year-to-year basis.

3.2.1 Program Overview

From 1995 to 2001, the inlet cleaning program has evolved from one that originally involved solely cleaning drain inlets to a program that involves the documentation and inventory of all (and in recent years, to a portion of) drain inlets for location, size, and debris accumulation volumes as part of an inspection phase then followed by an inlet cleaning phase.

The following sections summarize the inlet cleaning program and are grouped according to the years in which programs were similar.

3.2.1.1 Inlet Cleaning Program - 1995

In 1995, an enhanced drain inlet cleaning program was conducted in Caltrans District 7, which encompasses Los Angeles and Ventura Counties. Since all inlets were designated for a cleaning, no inspections to evaluate inlet deposition nor estimated solids volume quantities were conducted.

3.2.1.2 Inlet Inspection and Cleaning Program – 1996 to 2001

3.2.1.2.1 Program Summary - 1996

For the 1996 cleaning program, all inlets in District 7, under the jurisdictional boundary of the Los Angeles Regional Water Quality Control Board (RWQCB) were inspected prior to cleaning. The cleaning goal was to identify at least 2,000 drain inlets with the most volume of solids accumulation. These inlets were designated as "Tier II" inlets.

In 1996, 20,796 inlets were inspected with an estimated solids volume of 1,681 cubic meters. Of these inspected inlets, 4,155 inlets were identified for cleaning with a volume of 939 cubic meters. Three separate cleanings were conducted on these inlets beginning fall 1996 and then on two other occasions during the winter season. Other available data was limited for cleaning year 1996.

3.2.1.2.2 Program Summary – 1997, 1998

The drain inlet cleaning program was modified again beginning in 1997. During the inspection process, inlet deposition was recorded by estimating the average depth of the inlet debris taken at three separate measurement points for each inlet.

Inlets with six inches or more of deposition were designated for cleaning, with a goal of cleaning at least 4,500 drain inlets. Overall, 22,705 inlets were inspected with an estimated accumulated solids volume of 1,818 cubic meters. Of these inspected, 4,573 inlets were designated for cleaning with an estimated volume of 1,142 cubic meters. A total of 4,750 inlets were actually cleaned one time resulting in solids removal of 1,235 cubic meters.

Additional information pertaining to the inlets was recorded in a database, such as:

- Inlet type
- Discharge pipe size
- Inlet dimensions
- Location information (route, post mile, direction, shoulder location, GPS coordinates, etc.)
- Roadway conditions (cut, fill, at grade)
- Surrounding site conditions (vegetated slopes, presence of soundwall)

This revised cleaning program also included an inlet numbering and marking system.

In 1998, a similar inspection program as 1997 was conducted with an identical cleaning goal of 4,500 inlets.

To determine what depth of inlet accumulation would be used as a target threshold for cleaning, a random pre-inspection of inlets throughout the system was conducted. The results of this pre-inspection suggested that less solid material was present in the overall system in 1998 compared to 1997. Based on this pre-inspection information, a depth of five inches or more of solid material was selected as the initial target for cleaning inlets.

A total of 22,814 drain inlets were inspected and 4,575 inlets were identified for cleaning. Total volume in the system was estimated to be 1,233 cubic meters with 700 cubic meters of material found to be in the inlets identified for cleaning.

3.2.1.2.3 Program Summary – 1999, 2000

The inspection and cleaning strategy for the 1999 and 2000 cleaning years required 75%-80% percent of the total volume in inspected inlets to be cleaned from the inlets.

In 1999, 20,614 inlets were inspected with an estimated accumulated volume of 1,352 cubic meters. Of the inlets inspected, 7,580 inlets were identified for cleaning. Based on this estimate, Caltrans was required to clean between 1,014 to 1,082 cubic meters of solid debris.

A strategy for cleaning was applied in order to meet the requirement. For primary roadways, inlets with deposition of 4 inches or greater were selected for cleaning while inlets on secondary roadways were designated for cleaning based on inlet deposition of 3 inches or more. The inlet depth threshold was re-evaluated throughout the inspection program to determine if a reduced threshold would help to achieve the 75% to 80% volume removal criteria.

By applying this strategy, Caltrans cleaned 7,352 inlets resulting in the removal of 955 cubic meters of material. Two hundred twenty-eight inlets were identified for cleaning but not cleaned due to lane closure conflicts with roadway construction projects.

Caltrans also received credit towards the total solid removal requirement by removing debris from pump houses. Since pump houses were cleaned, Caltrans was not required to clean those inlets (2,100 inlets) that flow to the pump houses.

A maximum allowable credit of 129 cubic meters from a total of 784 cubic meters removed from 47 pump houses was applied toward the total removal. Thus, a removal total of 1,084 cubic meters was credited for the 1999 cleaning year.

For cleaning year 2000, a target threshold accumulation depth was also used to determine which inlets should be cleaned. Based on data from 1997, 1998, and 1999 cleaning years, drain inlets on primary roads with a solids depth of four or more inches was again used as a threshold for designated cleaning. For secondary roads, a threshold depth of three or more inches was used as the target threshold.

As the cleaning process progressed, the threshold was reduced to three inches or more of solid depth for all roadway types in order to better meet the 75% to 80% cleaning goal.

A total of 21,779 inlets were inspected with a total volume estimate of 1,234 cubic meters. Of these inspected inlets, 5,189 inlets were identified for cleaning with an estimated volume of 734 cubic meters. Based on the cleaning requirements, Caltrans would need to remove between 926 cubic meters and 988 cubic meters.

Of those inlets designated for cleaning, 5,155 inlets were actually cleaned. A total of 34 inlets were not cleaned, because they could not be located or because of construction conflicts. An additional 1,167 inlets not initially designated for cleaning were cleaned in order to increase the total volume removal to meet the 75% volume minimum required. These inlets contained material with less than 3 inches of material with a total volume of 81 cubic yards. In total, 6,322 inlets were cleaned with removal of 793 cubic meters of solid material.

Caltrans also received credit towards the total solid removal requirement by removing debris from pump houses. A maximum allowable credit of 135 cubic meters from a total of 988 cubic meters removed from 49 pump houses was applied toward the total removal. Thus, a removal total of 928 cubic meters was recorded for the 2000 cleaning year.

3.2.1.2.4 Program Summary - 2001

In 2001, the Drain Inlet Cleaning Program was revised. This revised cleaning program was to be conducted through the 2003 cleaning year and re-evaluated after the 2003 cleaning. The program includes:

- Cleaning inlets inside a defined Core Area
- Cleaning targeted inlets outside the Core Area
- Cleaning pump houses
- Cleaning other drainage structures including storm water BMPs.

The cleaning goal changed in 2001 to a pre-determined volume of 897 cubic meters (1,173 yd^3). This total solids removal volume was based upon the average volume removed in the previous four years from 1997 through 2000. This Core Area contains approximately 9,600 inlets not including those that flow to pump houses. The Core Area is defined as the area bounded by the following primary roadways: 405, 105, 605, 210, 134, and 101. Figure 3-3 illustrates the Core Area. The following primary roadway segments form the Core Area:

- 405 between 105 and 101
- 105 between 405 and 605
- 605 between 105 and 210

Core Area
Primary Roadway Segments
Secondary Roadway Segments

Figure 3-3
California Department of Transportation - District 7
2001 Drain Inlet Inspection and Cleaning Program

- 210 between 134 and 605
- 134 between 101 and 210
- 101 between the beginning of the route and 405
- 110 between 105 and end of route
- 710 between 105 and end of route
- 2 between 101 and 134
- 5 between 605 and 134
- 60 between beginning of route and 605
- 10 between 405 and 605

The following secondary road segments are also included in the Core Area:

- SR19 between 105 and 210
- SR72 between 605 and Montebello City Limits
- SR187 between 405 and 10
- SR2 between La Brea Boulevard and 101

To accomplish this cleaning goal, inlets on the right shoulder and at on/off ramps within the Core Area were inspected. In cases where four or more inches of solids accumulated in the inlet, these inlets were designated for cleaning.

Other inlets were "targeted" for cleaning based only on the previous four years of inspection cleaning data. These potential "targeted" inlets were then selected from those inlets located in non-Core Areas, and left shoulder inlets within the Core Area.

Drain inlets which had historical solids accumulation of greater than or equal to five inches, for two of the four previous data years, were designated for cleaning. Segments of roadway with targeted inlets were then designated for cleaning based on reference points such as streets, bridge over-crossings, etc.

These segments of roadway were then posted for temporary road closures and cleaned after lane closures were set. All targeted inlets along segments between primary locators were then cleaned. Inlets within these targeted segments not specifically identified for cleaning were also cleaned, if at least one inch of solids accumulation was in the inlet.

For the 2001 cleaning, credit was again given for cleaning pump houses. Inlets flowing to these pump houses were not inspected or cleaned.

By applying this strategy for inspection and cleaning, 6,227 inlets at right shoulder and on/off ramps within the Core Area were inspected. Of these inspected inlets, 1,300 inlets were identified and marked for cleaning. Of those marked for cleaning, 1,151 inlets were cleaned, resulting in the removal of 219 cubic meters. For targeted inlets, 6,154 inlets were cleaned with a total volume of 1146 cubic meters removed. Thus, the total number of Core Area and targeted inlets cleaned was 7,305, with a total removal volume of 1365 cubic meters. Forty-nine pump houses were cleaned which resulted in an additional credit of 139 cubic meters.

3.2.1.2.5 Comparison of Data from 1996 to 2001

Table 3-1 shows a comparison of the inspection program on a year-to-year basis for available data. The table further shows the number of inspected inlets, solid volume recorded, and volume per drain inlet, as a distribution by inlet location (right shoulder, left shoulder, on/off ramps, and transition/auxillary lanes). The table also summarizes the number of inlets inspected each year beginning in 1996 and the total volume of solid material estimated in those inlets.

For those inlets identified for cleaning based on selected inlet depth thresholds, the solids volume content in each inlet and calculated volume per inlet information is also listed. The highest total volume was measured in 1997 during the inspection phase with 1,818 cubic meters. A general decreasing trend was observed for the total estimated volume within inspected inlets from 1997 to 2000. For 2001, only drain inlets within the designated Core Area were inspected.

In 1998, a greater number of inlets (22,814) were inspected compared to that of 1997 (22,705 inlets). Despite this increased number of inspected inlets, the total volume in these inlets was determined to be significantly less. For 1998, 1,233 cubic meters of solids was determined compared to 1,818 cubic meters in 1997.

For all years, the greatest total volume accumulated in right shoulder inlets because they were also the greatest number of inlets inspected. From an average volume per inlet basis, inlets located on the left shoulder/median accumulated the greatest amounts. Inspection of left shoulder inlets was discontinued in 2001.

Table 3-2 summarizes data for the inlets actually cleaned for each year from 1997 to 2001. For the 1997 and 1998 cleaning years, the cleaning program had a goal of cleaning 4,500 inlets. For the 1999 and 2000 cleaning years, the program goal was 75% to 80% of the estimated volume in all inspected inlets.

Table 3-1
Summary of Drain Inlet Inspection Program
1996-2001

	Total Drain Inlets			Drain Inlets Identified to be Cleaned		
	Inlets	Volume (m^3)	Volume Per Drain Inlet (m^3)	Inlets	Volume (m^3)	Volume Per Drain Inlet (m^3)
1996						
Total	20,796	1,681	0.084	4,155	939	0.230
1997						
Total	22,705	1,818	0.080	4,573	1,141	0.249
Right Shoulder	11,340	950	0.084	1,928	566	0.294
Left Shoulder Median	4,543	454	0.100	1,600	344	0.215
On/Off Ramps	5,332	304	0.057	739	164	0.222
Transition/Auxiliary Lanes	1,490	110	0.074	306	67	0.220
1998						
Total	22,814	1,233	0.054	4,290	700	0.163
Right Shoulder	10,539	628	0.060	1,918	352	0.184
Left Shoulder/Median	5,320	322	0.060	1,523	210	0.138
On/Off Ramps	5,314	226	0.043	693	109	0.158
Transition/Auxiliary Lanes	1,641	57	0.035	156	28	0.181
1999						
Total	20,614	1,352	0.066	7,580	1,002	0.132
Right Shoulder	9,501	623	0.066	2,828	441	0.156
Left Shoulder/Median	5,046	420	0.083	3,134	360	0.115
On/Off Ramps	4,706	232	0.049	1,309	158	0.121
Transition/Auxiliary Lanes	1,361	76	0.056	309	43	0.138
2000						
Total	21,779	1,234	0.057	5,189	734	0.142
Right Shoulder	9,750	592	0.060	1,852	339	0.183
Left Shoulder/Median	5,292	321	0.060	1,892	203	0.108
On/Off Ramps	4,868	243	0.050	1,032	148	0.143
Transition/Auxiliary Lanes	1,869	80	0.043	413	44	0.106
2001						
Total	6,227	399	0.064	1,300	246	0.189
Right Shoulder	3,811	293	0.080	935	192	0.205
On/Off Ramps	2,147	95	0.044	322	48	0.150
Auxiliary Lanes	269	11	0.039	43	5	0.125

However, in the 2001 and 2002 cleaning program, the cleaning goal was to remove at least 897 cubic meters (1173 yd^3), the average volume of solids removed from inlets over 1997 through 2000 cleaning years. Since the cleaning goals varied during the course of the cleaning program, the actual number of inlets cleaned is a relative measure of the program.

Additionally, data is also limited to cleaning years 1997 to 2001. Cleaning data for 1996 was not available, while 2002 inspection and cleaning data is not yet reported.

Table 3-2
Summary of Drain Inlets Cleaned 1997 to 2001

	Drain Inlets Cleaned		
	Number of Inlets	**Volume (m^3)**	**Volume per Drain Inlet (m^3)**
1997	4750	1235	0.26
1998	4576	724	0.16
1999	7352	955	0.13
2000	6322	793	0.12
2001	7305	1365	0.18

3.2.1.2.6 Scheduling and Operational Issues

The inspection and cleaning of inlets have had a significant impact on traffic due to the need for the establishment of temporary moving and static lane closures. Between 1997 and 2001, nine traffic accidents have occurred during the inspection and cleaning program. Despite the establishment of proper traffic control measures, motorists have rear-ended the rear shadow vehicle during these traffic incidents.

The moving lane closures are of significant safety concern. Moving lane closures are employed when conducting inspections. Over eighty percent of the drain inlets inspected require temporary closure of a traffic lane. For cleaning operations, static lane closures are required.

The current program requires significant coordination between the Caltrans Maintenance Storm Water Unit and Traffic Management Center (TMC) staff. Static lane and moving lane closure requests are submitted electronically to the Traffic Management Center (TMC) staff, who then review the request and approve closures based on the scheduled traffic closure charts and potential conflicts with other maintenance or construction activities. After the TMC approves the scheduled closures, these lane closures are reported to the media for dissemination for public notice and posted on the Caltrans website.

In previous cleaning years, lane closures were requested for as long as a one-week period to allow for sufficient time for cleaning or to account for unforeseen issues such as equipment failures. Maintenance Storm Water Unit staff have improved in coordinating this effort, because of greater experience in estimating the approximate time required to inspect and clean inlets. During the initial two years, cleaning was performed frequently in the daylight hours. However, as a result of the difficulty in identifying traffic availability time slots, the cleaning operations have increasingly been performed during night hours.

Inspections, however, continue during daylight hours from Monday through Friday, 9AM to 3PM. Night shifts are conducted on Sunday through Thursday, between 7:30 PM to 5AM. These night inspections focus on road segments which are under closure restrictions during the daylight hours and are accessible only during the night shift hours.

The current operational practice is to close a segment of roadway and clean all designated or targeted inlets within the segment. By establishing closures for a defined segment of roadway, all the inlets within the segment except for those with solids accumulation less than one-inch in depth are cleaned. Traffic control can be established with greater efficiency and safety by not having to setup and breakdown traffic control repeatedly.

3.2.2 Data Analysis Summary

3.2.2.1 Inlet Inspection and Cleaning Data – 1996 to 2001

This section summarizes the results of the drain inlet inspection data analyses conducted on data collected between 1996 and 2001, as reported in the District 7, 2001 Drain Inlet Inspection and Cleaning Program Final Report (Caltrans, 2002). The purpose of the analysis was to determine if a more effective method for identifying inlet cleaning could be established based on any possible factors that are correlated to inlet solids accumulation.

The data analysis was made with the following assumptions:

- Data for watershed characteristics, airshed characteristics, and meteorologic conditions that could be associated with drain inlets is limited.
- Drain inlet inspection data collected in 1996, 1997, 1998, 1999, 2000, and 2001 are available. Data from 1996 was not of adequate quality and availability for use in this analysis.
- Since the threshold depth criteria for inlet inspections varied from year to year, annual inspection data needs to be interpreted with this consideration.

- Data analysis was conducted on a data set consisting of 4738 common drain inlets that were inspected in <u>each</u> of the five years from 1997 to 2001. For 2001, the inspections were limited to 6227 inlets located on the right shoulders and ramps, within the Core Area.

Various statistical tests (Descriptive Statistics, Paired t-test, One-way ANOVA, Turkey's Multiple Comparison Procedure, Two-Way ANOVA, One-Way Repeated Measures ANOVA, and Correlation) were applied to the data set in order to determine if the volume of solids accumulated in inlets could be associated or correlated to other factors such as roadway type, freeway route, inlet area, inlet depth, discharge pipe size, and traffic volume. The identification of factors that affect solids accumulation could then be considered in developing a more effective drain inlet and inspection cleaning program.

The results of the data analysis on 4738 common inspected inlets for years 1997 to 2001 indicate the following:

- Inlets on secondary roadways (streets) accumulate greater volumes on average than inlets in other roadway types, but represent the smallest number of inlets. Freeways (primary roadways), with the greatest number of inlets, had a lower average volume per inlet.

- Analyzing solids volume by route, the average volume per mile, and average per drain inlet appear to be good indicators for the frequency of inspection and cleaning of drain inlets. Route 110 was among the top seven routes for average volume per mile and the average volume per inlet for all five years of data.

- Data analysis indicates no correlation between inlet solids volumes and inlet depth, inlet area, and inlet discharge pipe size.

- Data analysis indicates no correlation between volumes of solids accumulation and traffic volume.

- In general, when the average annual rainfall is higher, the average solids volume is lower. This pattern was not consistent in 2001. Greater average rainfall amounts accumulated in 2001 than in 2000, yet slightly greater average solids volumes in inlets were observed. Rainfall seemed to show correlation to accumulated volumes in drain inlets, but did not prove to be a good predictor for identifying specific drain inlets for cleaning because of the unpredictability of local rainfall patterns.

- Evaluation of the cleaning/inspection history for inlets inspected in the Core Area with five or more inches of solids accumulation suggests that Routes 110, 605, and 5 tend to have the greatest number of inlets with five or more inches of solids.

- Evaluating cleaning and inspection history of individual inlets appears to be a powerful tool for predicting the frequency with which inlets will need to be cleaned. Some inlets have required yearly cleaning, while others have not. This cleaning and inspection history provides a potential means to target inlets for future cleaning.

Section 4
Drain Inlet Cleaning Effectiveness Assessment

This section provides an overall assessment of the effectiveness of an enhanced drain inlet cleaning program based on the monitoring and data analysis results from the DICE and STDS studies and the information developed from six years of drain inlet inspection and cleaning in District 7. Section 4.1 presents an assessment of the water quality effectiveness and Section 4.2 reviews the effectiveness with respect to litter. Finally, Section 4.3 presents a summary of program costs and other impacts.

4.1 Water Quality Effectiveness Assessment

After a number of years of drain inlet inspection and cleaning as well as five years of study conducted to determine the effectiveness of drain inlet cleaning on water quality, the following sections evaluate the effectiveness of these cleaning efforts.

4.1.1 Water Quality Monitoring Results

The goal of DICE was to determine whether drain inlet cleaning results in significant reductions in key water quality parameters in runoff discharged from Caltrans right-of way. As presented in Section 2, cleaning the drain inlets was found to have negligible impact on the measured quality of runoff discharged from the Caltrans highway system in District 7 based on statistical analysis of the combined dataset from 1996-1997 through 2000-2001. No statistically significant difference was found in the mean concentrations of runoff quality between catchments where cleaning was performed and those where cleaning was not performed for any of the parameters. The results are based on a substantial body of data taken over five years under varying hydrologic conditions and a number of different roadway conditions.

While this outcome was not intuitively predictable at the outset of the DICE study, a combination of factors that have been learned from the data and observations gained from all of the studies and activities described herein can provide some potential explanations for the findings. These include:

- Caltrans drain inlets on freeways and major highways are designed to be self-cleaning; that is without any sump or catch basin. Therefore, there is no dedicated storage volume for accumulation of sediments and other material. This design is in contrast to some inlets in local municipal storm drain systems, particularly older designs with long curb inlets that have much larger drop structures that can function as sumps. This distinction can be seen in the fact that the highest solids accumulations per inlet from the cleaning program data are found in the data from the state designated secondary highways that are local arterial streets.

- The solids accumulation is largely a dry weather process confirming that a cleaning program in the late summer or early fall will likely remove a greater mass of material and sediment from the system. However, the extent and characteristics of the material that does accumulate during the dry weather periods is a limited amount of sediment and any associated pollutants that can be transported largely by wind and vehicle movement, some litter (typically finer and disintegrated) and vegetative matter. In comparison, wet weather runoff can pick up and transport greater loads of all nature and size of potential pollutants that are then likely to be flushed through the drainage system and not deposited in the inlets.

- The majority of inlets accumulate negligible material even during the dry season. Therefore, the cumulative impact on the discharged water quality resulting from remaining material from a limited number of inlets in a catchment is negligible.

Given these factors, it is not that surprising that water quality in discharges from cleaned inlets was not found to be significantly different from uncleaned inlets.

4.1.2 Potential Load Reduction Assessment for Selected Constituents

While monitoring for water quality at storm drain outfalls for five storm seasons has not shown any significant difference in the measured water quality between cleaned and uncleaned drain inlets, information from all three studies was used to estimate the load of pollutants reduced through drain inlet cleaning to assist in comparing the effectiveness of drain inlet cleaning with other BMPs and control measures. To make this assessment, an estimate of average loads of key constituents removed through drain inlet cleaning in District 7 was compared to estimates for these same constituents of the total runoff from Caltrans right-of-way, within the area of District 7 covered by the DIIC program.

To help estimate pollutant loads from Caltrans right-of-way, a Water Quality Planning Tool was utilized. The Water Quality Planning Tool models the estimated storm water runoff loads from Caltrans facilities within a particular watershed for numerous constituents. This planning tool model was developed by Caltrans in conjunction with the California State University at Sacramento (CSUS) and the University of California at Davis (UCD) as part of the Caltrans Storm Water Program. For the planning tool model, Caltrans facilities include: roadways, maintenance yards, and park and ride lots. Therefore, the water quality loads assessment model includes runoff from all three Caltrans facilities and cannot be isolated for only roadway runoff loads.

However, since roadway facilities comprise the vast majority of the Caltrans right-of-way facilities relative to maintenance yards and park and rides, the load model is utilized for this loads assessment. The load model uses land area, estimated runoff coefficients, and local rainfall data to calculate runoff volume for each hydrologic unit within the State. The planning model tool also uses the Caltrans water quality monitoring database established from extensive water quality runoff monitoring at the outfall of Caltrans drainage systems to establish representative constituent concentrations. These representative concentrations for freeway runoff are then applied to determine the loads.

Total chromium, copper, lead, and zinc were chosen as constituents that can occur in Caltrans runoff in concentrations greater than the most stringent water quality objectives as noted in Section 2. Because the Water Quality Planning Tool was initially based on State-wide data that is several years old, more recent runoff data (1998-2001) obtained from monitoring within District 7 was used for the current comparison. The concentrations are as follows:

- Chromium: 9.72 μg/L
- Copper: 50.22 μg/L
- Lead: 112.39 μg/L
- Zinc: 228.48 μg/L

For the District 7 cleaning program, Malibu Hydrologic Unit 404 and Los Angeles-San Gabriel Hydrologic Unit 405 correspond to the areas in which inlet cleaning was performed. These watershed areas are based on the hydrologic units with sub-areas (HSAs) for the State of California, as listed in the Basin Plan for the Coastal Watersheds of Los Angeles and Ventura Counties, Los Angeles Regional Water Quality Control Board, 1994. Table 4-1 summarizes the total load for metal constituents such as copper, chromium, lead, and zinc for the estimated storm water runoff based on the Caltrans Water Quality Planning Tool, with using the recent District 7 water quality data.

Table 4-1
Estimated Storm Water Runoff Loads based on Caltrans Water Quality Planning Tool

Hydrologic Unit	Caltrans Watershed Area (hectares)	Copper-T (kg/yr)	Chromium-T (kg/yr)	Lead-T (kg/yr)	Zinc-T (kg/yr)
Malibu	378.8	82	16	185	373
Los Angeles – San Gabriel	4,948.9	953	188	2,124	4,398
Total	5,327.7	1,035	204	2,309	4,771

In order to estimate the mass of constituents potentially removed from drain inlets as a portion of the overall pollutant load that runs off from Caltrans right-of-way, the sediment composition and characteristics of inlet solid material was determined by using the STDS results and then applied to data from the DIIC program

From STDS observed data, inlet solid material was determined to be composed of 25% sediment, 20% litter, and 55% vegetation. The density of sediment was also determined to be 1913 kg/m^3. Further sampling analysis of the sediment component for selected metals showed the following fraction of metal within sediment:

- Chromium: 36 mg/kg
- Copper: 199 mg/kg
- Lead: 220 mg/kg
- Zinc: 570 mg/kg

Between 1997 and 2001, the average solids material removed from the drain inlets was 1014 cubic meters. The mass load of each constituent is calculated by the following equation and shown in Table 4-2.

Constituent Load = Fraction of Constituent in Sediment (mg/kg) * Volume of solids removed (m^3/yr) * Sediment Percentage of Solids (%) * Density of Sediment (kg/m^3) * Conversion Factors (1 kg/1,000,000 mg).

Table 4-2
Estimated Constituent Load Removed by Cleaning in District 7

	Fraction of Constituent in Sediment	Average Volume of Solids Removed	Sediment Percentage of Inlet Material	Density of Sediment	Estimated Load
Constituents	Mg/kg	m^3/yr	%	kg/m^3	kg/yr
Chromium	36	1,014	25	1,913	17.5
Copper	199	1,014	25	1,913	96.5
Lead	220	1,014	25	1,913	106.7
Zinc	570	1,014	25	1,913	276.4

4.1.2.1 Total Chromium

Table 4-2 shows the average quantity of total chromium estimated to be removed by inlet cleaning was 17.5 kg/year. From the runoff load model, 204 kg/year of total chromium runs off of Caltrans right-of-way within the cleaning program area. The mass load of total chromium removed by drain inlet cleaning is 8.6% of the predicted total chromium load.

4.1.2.2 Total Copper

Table 4-2 shows the average quantity of total copper estimated to be removed by inlet cleaning was 96.5 kg/year. Based on the runoff load model, 1,035 kg/year of total copper runs off of Caltrans right-of-way within the cleaning program area. The mass load of total copper removed by drain inlet cleaning is 9.3% of the predicted total copper load.

4.1.2.3 Total Lead

Table 4-2 shows that an average of 106.7 kg/year of total lead estimated to be removed from by inlet cleaning. Based on the runoff load model, 2,309 kg/year of total lead runs off of Caltrans right-of-way within the cleaning program area. The mass load of total lead removed by drain inlet cleaning is 4.6% of the predicted total lead load.

4.1.2.4 Total Zinc

Table 4-2 shows the average quantity of total zinc removed by inlet cleaning was 276.4 kg/year. From the runoff load model, 4,771 kg/year of total zinc is predicted to run off of Caltrans right-of-way within the cleaning program area. The mass load of total zinc removed by inlet cleaning is 5.8% of the predicted total zinc load.

4.1.2.5 Potential Cleaning Effectiveness

In summary, an extensive drain inlet cleaning program as practiced in District 7 over the past 6 years has the potential to remove only five to nine per cent of the total annual mass of selected metals that may be discharged from Caltrans right-of-way. Furthermore, it would be very difficult to significantly increase this performance because of the rapidly diminishing returns from cleaning more inlets with less material, while the cost and impact to the public substantially increase.

4.2 Litter Effectiveness Assessment

As discussed in Section 2.9, litter data was collected during the 2000-2001 DICE monitoring season. No obvious trends can be seen when data from the cleaned and uncleaned catchments is compared. On a per hectare basis, the cleaned catchments had both the highest and lowest dry litter amounts. Unit area dry litter amounts were higher in the cleaned catchments. Statistical analysis similar to that performed on water quality data is shown in Table 2-16. The statistical data further supports the observation that there is no quantitative difference in litter between cleaned and uncleaned inlets.

In a similar approach to that used to assess water quality effectiveness, this section evaluates the effectiveness of the drain inlet cleaning program by examining the estimated litter load that is cleaned from drain inlets during the Inlet Cleaning Program versus the total litter load runoff contributed from Caltrans watershed areas.

In order to determine the litter load removed from drain inlets as a portion of the overall litter load that runs off from Caltrans right-of-way, the Caltrans Water Quality Planning Tool is again utilized together with data from the various studies cited earlier. From the planning tool, the Caltrans watershed area is estimated to be 5328 hectares within the Malibu Hydrological Unit (404) and Los Angeles-San Gabriel Hydrologic Unit (405). Drain inlet cleaning has been performed within these two hydrologic units.

Based on the Litter Management Pilot Study (LMPS) and STDS results, an average annual litter load was determined to be 0.36 m^3/ha/yr.

In order to determine the litter portion from overall solid material that is removed during inlet cleaning, the estimated litter percentage (by volume) in drain inlets was determined by using data from the following studies:

- DICE Study – The study included visual observations of study-related drain inlets. Relative percent composition (by volume) of drain inlets was determined to be 18% litter, 27.5% vegetation, and 54% sediment.

- Solid Transport Deposition Study (STDS) – The study included visual observations of study-related drain inlets. Relative percent composition (by volume) of drain inlets was determined to be 20% litter, 55% vegetation, and 25% sediment.

Table 4-3 summarizes the estimated volume of litter cleaned by the DIIC program and compares it to the estimated annual litter load from Caltrans right-of-way within the cleaning program area. The estimated litter load of 1,918 m^3/yr is based on 0.36 m^3/ha/yr multiplied by the 5,328 hectares of Caltrans watershed area. Based on these calculations, the percent of total litter load estimated from Caltrans right-of-way that could be affected by drain inlet cleaning ranges from about 7-14%. Again, as noted under the water quality effectiveness assessment, cleaning substantially more inlets than under the current program would be unlikely to result in capturing a much higher percentage because of the diminishing returns.

Table 4-3
Litter Cleaning Effectiveness

Year	Annual Volume Cleaned from Inlets	Number of Inlets Cleaned	Litter Percentage	Litter Cleaned Annually	Estimated Load from Caltrans Watershed	Percent Cleaned
	m^3/yr	Inlets	%	m^3/yr	m^3/yr	%
1997	1,235	4750	20	244.2	1,918	12.7
1998	724	4575	20	143.0	1,918	7.5
1999	955	7352	20	188.7	1,918	9.8
2000	793	6322	20	156.6	1,918	8.2
2001	1,365	7305	20	269.7	1,918	14.1

In watersheds where a trash TMDL has already been adopted (Los Angeles River, Ballona Creek) with a target reduction to zero trash discharged, continuation of drain inlet cleaning would provide a minor contribution toward achieving this target.

4.3 Program Costs and Impacts

The most current contract costs are approximately $500,000 for drain inlet inspections and $3 million for drain inlet cleaning for program year 2002.

Caltrans Maintenance staff costs are estimated at five (5) person-years (PY= 1768 hours) for the two-month inspection and cleaning effort. Based on an average annual salary of $50,000, Inlet Cleaning Program costs are estimated at $250,000 per year.

This estimate is limited to Maintenance Storm Water Unit staff participating in coordinating the District 7 program, as well Maintenance field representatives conducting field oversight during the inspection and cleaning effort. Approximately four Maintenance staff conducted full-time coordination efforts during the two-month cleaning period, while Maintenance field personnel utilized are dependent upon the number of contractor inspection and cleaning crews in the field. Costs do not include staff time incurred by other Caltrans departments such as Traffic Management Center staff in coordinating traffic lane closure requests.

For comparison with other BMPs, a relative cost per kg of a representative constituent such as copper can be estimated. Assuming typical annual costs of about $4,000,000 year for the District 7 program including the above cited costs and allowances for traffic control coordination and other miscellaneous costs, this results in a cost of approximately $42,000/kg/yr of copper removed.

Section 5
Conclusions

Based on the results and findings of the DICE monitoring study, the STDS and six years of data and observations from the District 7 DIIC program, the following conclusions can be drawn.

- Cleaning the drain inlets was found to have negligible impact on the measured quality of runoff discharged from the Caltrans highway system in District 7 based on statistical analysis of the combined dataset from 1996-1997 through 2000-2001. No statistically significant difference was found in the concentrations of runoff quality between catchments where cleaning was performed and those where cleaning was not performed for any of the parameters. The results are based on a substantial body of data taken over five years under varying hydrologic conditions and a number of different roadway conditions.

- Based on litter data collected during the 2000-2001 DICE monitoring season, no obvious trends can be seen when data from the cleaned and uncleaned catchments is compared. On a per hectare basis, the cleaned catchments had both the highest and lowest dry litter amounts. Unit area dry litter amounts were higher in the cleaned catchments. The statistical data further supports the observation that there is no quantitative difference in litter discharged from cleaned and uncleaned inlets.

- A combination of factors learned from the data and observations from all of the studies and activities provide insights and potential explanations for the above findings. These factors include:

    - Caltrans drain inlets are designed to be self-cleaning. Most pollutants pass through the inlets to the drainage system during runoff events, when material is typically flushed from, not deposited in the inlet drop structure.

    - Accumulation of material that does occur results largely from incidental localized dry weather transport processes. The majority of inlets in any given catchment typically accumulate low to negligible deposition of materials.

- An extensive district-wide cleaning and inspection program such as has been conducted in District 7 for the past six years is estimated to remove between five and nine percent of the total loading of several metals and between seven and 14 percent of litter typically found in runoff from Caltrans right-of-way.

- The enhanced drain inlet cleaning program that has been conducted in District 7 requires substantial costs and resources and results in significant potential disruption and safety hazard to both workers and the driving public. Although the program has been refined and targeted over the past six years, it still requires close to $4,000,000 in contract costs, Caltrans labor and other miscellaneous costs.

- Continue a baseline program for all Caltrans facilities of routine inspection and conduct cleaning and maintenance as required to maintain function and hydraulic capacity. This approach will target problem areas and remove material from drain inlets that tend to accumulate the largest quantity of material.

- Use the findings presented in this report to consider further reduction in or elimination of current enhanced drain inlet cleaning programs based on not meeting maximum extent practicable criteria for key pollutants in runoff such as metals. As long as enhanced cleaning programs continue, the programs should be focused on minimizing the cost and disruption to traffic and worker and public safety. General suggestions include:

  - Eliminate pre-season system-wide inspections

  - Clean only right shoulder inlets

  - Focus on core areas or other known areas of significant historical accumulation

- For watersheds with adopted trash TMDLs, focus compliance efforts on BMPs other than drain inlet cleaning. As drain inlet cleaning does not appear to be effective in achieving a high percentage reduction in litter, it is likely to be more cost-effective to focus on a combination of litter reduction BMPs and structural controls to meet the TMDL requirements.

Caltrans Drain Inlet Cleaning Efficacy Study 2000-2001 Water Quality and Litter Monitoring Program Sampling and Analysis Plan

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California Department of Transportation
Environmental Program
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Sacramento, California 95814

Caltrans Drain Inlet Cleaning Efficacy Study 2000-2001 Water Quality and Litter Monitoring Program Sampling and Analysis Plan

October 2000

Effective Dates:

November 1, 2000 to April 30, 2001

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Section 1
Introduction

This Sampling and Analysis Plan describes the monitoring to be performed during the fifth year of the Caltrans Drain Inlet Cleaning Efficacy Study Water Quality and Litter Monitoring Program (Monitoring Program). The 2000-2001 Monitoring Program generally represents a continuation of the study approach that was developed for the 1996-1997, 1997-1998, 1998-1999 and 1999-2000 Monitoring Programs for water quality sampling of storm water runoff discharged from selected catchment areas within District 7. Litter collection and analysis has been added for the 2000-2001 Monitoring Program. Refinements to the Monitoring Program will also be undertaken to improve data quality and the overall reliability of the program. Sections detailing litter sample collection and analysis have been included in this Sampling and Analysis Plan.

Catchment areas are defined as the section of highway, associated right-of-way, and offsite area (if any) that drain to a single discharge monitoring point. Discharges from the catchment areas typically flow into municipal storm drain systems or directly into downstream receiving waters. Under this study, each selected catchment area consists of a series of drain inlets that are connected through a network of storm drainpipes along representative sections of freeway located in Caltrans District 7. Water quality monitoring and litter collection is performed at the outlet of each catchment to characterize storm water from the upstream drain inlets.

The study approach involves selecting an even number of catchment areas within District 7, which are then divided into two groups. Half of the catchment areas are used as the "test" catchment areas and the other half are used as the "control" catchment areas. All drain inlets in the "test" catchment group are cleaned three times during the wet season whereas no drain inlet cleaning is performed in the "control" catchment group. In subsequent years, the groups of "control" and "test" catchment areas are switched each season and a similar level of water quality monitoring is performed. This year, a new set of eight (8) catchment areas are being used, so a new cleaning cycle will be implemented.

Three (3) catchment areas from the 1999-2000 Monitoring Program will continue to be used along with five (5) new sites.

1.1 Objectives

The overall objective of the Monitoring Program is to collect data which can be used to evaluate the potential effectiveness of drain inlet cleaning as a management practice for improving the water quality of highway storm water runoff. Specifically, the data collected under the monitoring program are designed to help assess the effects of drain inlet cleaning on the water quality of storm water runoff.

In order to accomplish these objectives the following data will be generated or collected:

- Event mean concentrations (EMCs) of target parameters during monitored storms
- Particle size fractionation on the solids removed from drain inlets during cleaning
- Litter volume, wet weight, and dry weight

Statistical analyses will be performed to detect differences between data collected from catchment areas which were cleaned and data collected from catchment areas which were not cleaned.

All drain inlets within cleaned catchment areas will be cleaned on three separate occasions during the Monitoring Program. Initial cleaning will occur in October 2000, and subsequent cleanings are tentatively scheduled for January 2001, and March 2001.

Materials from the cleaned inlets will be removed and the total from each catchment weighed. In addition, before cleaning, the volume of material within the inlet will be measured. For each cleaned catchment, a material sample will be obtained from each drain inlet and composited into a single catchment sample. These composite samples will be sent to the contracted laboratory for particle size analysis. Sampling methods are described in detail in Section 4.2.

1.2 Data Analysis

During the 1996-1997, 1997-1998, 1998-1999 and 1999-2000 Monitoring Programs, two independent groups of data were collected; data from monitoring stations where drain inlets were cleaned and data from monitoring sites where drain inlets were not cleaned. A similar data collection effort will be conducted during the 2000-2001 Monitoring Program. For each monitored 2000-2001 storm event, water quality, litter, and flow data will be obtained. The water quality data will be used to determine EMCs for each of the target parameters generated from each catchment area. Litter data will be used to determine whether cleaning the drain inlets affects the volume and weight of litter discharged at the end of pipe during the rainy season. Statistical techniques will be applied to the EMCs and litter data in order to evaluate the differences between data collected from catchment areas which were cleaned and data collected from catchment areas which were not cleaned.

1.3 Summary of Sampling Methods

The primary water quality sampling method utilized under the Monitoring Program involves collection of a flow-weighted composite sample during the entire hydrograph for monitored storm events. The flow-weighted composite sample will be collected using an automatic sampler that is interfaced with a flow meter to provide ‘real time' flow pacing. Laboratory analysis of a single flow-weighted composite sample will provide an estimate of the event EMC.

Automatic samplers will be configured to collect flow composite samples based on direct measurements of flow velocity and stage or where velocity measurements are not practical, flow will be based on a flow-stage relationship (i.e., rating curve approach). The aliquot sampling interval will be selected so that there is good sample coverage of monitored storm events. Flow rates at these locations are measured in order to quantify the amount of runoff discharged and allow for the collection of flow proportional samples. Flow temperature field measurements will be made whenever a crew is in the field and the storm water is flowing.

A mesh bag attached to the end of the outfall collects all litter. To facilitate attachment of the bag, modifications to the outfall are required. To capture as much litter as possible and still allow water to flow through, the bags have one-quarter inch openings. The bag will be collected at the end of the storm for the sample to be representative of the whole storm. In addition, bags will be collected prior to the storm to collect any litter that may have accumulated in between storms.

1.4 Parameters for Chemical and Litter Analyses

The selection of the parameters for the Drain Inlet Cleaning Efficacy Study Water Quality and Litter Monitoring Program was based on the “parameters for analyses" identified in the *Caltrans Guidance Manual: Stormwater Monitoring Protocols, May 2000*. A list of the selected chemical parameters is presented in Table 1-1.

The selected parameters for litter analysis includes weight, and volume. The categorical types of gross pollutants are vegetative and non-vegetative.

1.5 Roles and Responsibilities

In order to ensure that the Monitoring Program is conducted in an effective manner, the following roles are required: Task Manager, Storm Event Coordinator (SEC), Field Team Leader, and Field Team Assistant. Figure 1-1 shows the overall organization of the key personnel. The responsibilities for each of these positions are discussed below.

Task Manager

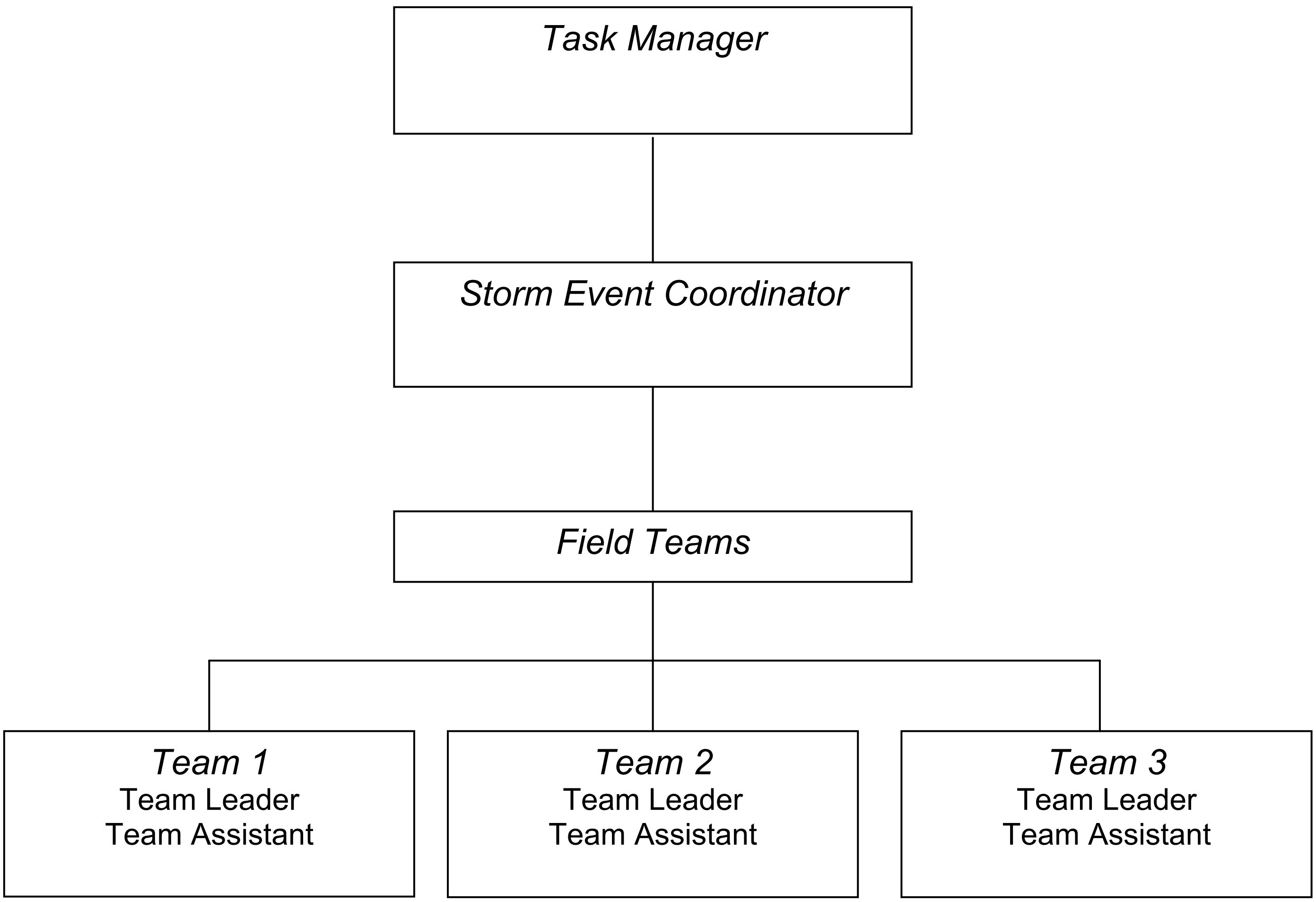
The Task Manager has overall responsibility for the storm water sampling program. The Task Manager will work closely with the Caltrans Project Coordinator to finalize decisions regarding storm selection, allocation of personnel resources, and budget, and to discuss any problems encountered during the sampling program.

Storm Event Coordinator (SEC)

The SEC is responsible for programming and operating the monitoring equipment, tracking wet weather events, estimating the sampling interval for each site based on projected rainfall volumes, directing field team activity, and laboratory coordination. The SEC is also responsible for insuring that field crews have all necessary equipment, answering technical questions and troubleshooting equipment problems during an event. Two other SECs will be ready to assist the program as needed.

Table 1-1
List of Target Parameters
Caltrans Drain Inlet Cleaning Efficacy Study
Water Quality Monitoring Program

Parameter	*Sampling Method*
Metals (Total and Dissolved)	
Arsenic	Automatic Sampler
Cadmium	Automatic Sampler
Chromium	Automatic Sampler
Copper	Automatic Sampler
Lead	Automatic Sampler
Nickel	Automatic Sampler
Zinc	Automatic Sampler
Nutrients	
Total Phosphorus	Automatic Sampler
Dissolved Phosphorus	Automatic Sampler
Dissolved Ortho Phosphate	Automatic Sampler
TKN	Automatic Sampler
Nitrate-N	Automatic Sampler
General	
Temperature	Field Measurement
Hardness	Automatic Sampler / Field
pH	Automatic Sampler / Field
Specific Conductivity	Automatic Sampler
Total Organic Carbon	Automatic Sampler
Dissolved Organic Carbon	Automatic Sampler
Total Suspended Solids	Automatic Sampler
Total Dissolved Solids	Automatic Sampler
Volatile Solids	Automatic Sampler


Task Manager
Storm Event Coordinator
Field Teams
Team 1
Team Leader
Team Assistant
Team 2
Team Leader
Team Assistant
Team 3
Team Leader
Team Assistant

Field Teams

There will be three Field Teams consisting of 2 people as specified in the Health and Safety Plan. Each team will have a designated leader and a assistant with the following responsibilities:

Field Team Leader: The Field Team Leader will be responsible for monitoring station set-up, start up of the monitoring equipment, sample collection, monitoring station shut-down, transporting the samples to the laboratory, and completing all applicable field documentation (logs, checklists, chain-of-custody forms, etc.). The Field Team Leader will also be responsible for routinely inspecting equipment and calibration and maintenance of equipment as needed.

Field Team Assistant: The Field Team Assistant will provide assistance to the Field Team Leader throughout a sampling event.

Section 2
Data Use and Quality Objectives

The overall Quality Assurance/Quality Control (QA/QC) objective for the Caltrans Drain Inlet Cleaning Efficacy Study 2000-2001 Water Quality and Litter Monitoring Program is to ensure that the data collected is of documented quality for the purposes of this program. Specific data uses and quality assurances are described in the following sections.

2.1 Data Use

The overall objective of the water quality monitoring program is to evaluate the potential effectiveness of the Caltrans Drain Inlet Cleaning Program. Specifically, all data collected during the water quality monitoring program will be used to:

- Compare and distinguish data collected from catchment areas which were cleaned from those that were not cleaned
- Evaluate the effects of drain inlet cleaning on the water quality including litter content of storm water runoff
- Calculate event mean concentrations (EMCs) of target parameters
- Evaluate data on particle size fractionation and develop a list of general characteristics for the materials removed during the drain inlet cleaning process.

2.2 Quality Assurance Objectives

Quality assurance objectives for measurement data are usually expressed in terms of precision, accuracy, representativeness, completeness, and comparability. In order to achieve these objectives, data must be:

- Of known quantitative statistical significance in terms of precision and accuracy, at levels appropriate for each stated data use for the project
- Representative of actual site physical and chemical conditions
- Complete to the extent that necessary conclusions may be reached
- Comparable to previous and subsequent data and other stormwater quality studies conducted by Caltrans

Brief descriptions of the QA/QC data that will be collected to assess precision, accuracy, representativeness, completeness, and comparability are provided in the following paragraphs.

Precision and accuracy are for information generated from relatively homogeneous samples and is not applicable to the results from litter particle fractionation, volume or weight.

2.2.1 Precision

Precision for chemical data is a measure of mutual agreement among individual measurements of the same property, usually under prescribed similar conditions. Split samples will be used to verify the precision of the laboratory analysis. Split samples will be prepared in the field by splitting a volume of sample. Both sample volumes will be delivered to the contracted laboratory for identical analysis. Split samples will be prepared for both grab samples and flow-weighted composite samples. Split samples will be prepared and analyzed at a minimum frequency of one per 20 sampling event. The precision of flow and rainfall data will not be quantified but will be assessed by comparison with other rain gauges in the vicinity of the sampling station.

2.2.2 Accuracy

Accuracy for chemical data is a comparison of a measured value with a known or "true" value. Accuracy is also a measure of the bias in a system. QC criteria for accuracy are primarily related to laboratory results of analyses of method blanks and matrix spike/duplicate samples that will <u>not</u> require collection of additional samples in the field.

Spot checks will be performed to field check the accuracy of flow and rainfall measurements. Flow data will also be checked against Manning equation estimates where site conditions are suitable. Manning equation results will be used to flag discrepancies of larger than fifty percent and indicate a need to perform additional field flow meter accuracy checks.

2.2.3 Representativeness

Representativeness for chemical data is the degree to which data accurately and precisely represents the true value of a characteristic of a population, parameter variations at a sampling point, a process condition, or an environmental condition, intended to be characterized. In general, the representativeness of the water quality data collected during this monitoring program will be controlled as a result of: proper monitoring network design; appropriate selection of field methodologies; proper sample preparation, preservation and handling; appropriate selection and execution of analytical methodologies; consistent sample identification; and accurate reporting of results. Representativeness criteria are presented to ensure that sampling is performed during "representative" hydrometeorological conditions. Monitoring will target wet weather events that exceed a minimum precipitation threshold (0.20 inches of rain), a 50 percent chance for rain, and a minimum dry period between storm events (72 hours). Since it is not possible to predict storm characteristics in advance with any great certainty, it may be necessary to accept monitoring data from a limited number of events that do not completely meet the representativeness criteria.

Representativeness for litter data will be maintained by collecting all the litter within a catchment area including any open channels leading to the catchment area, closing the litter bags to contain all the litter within the bag, and transporting the litter bag without damage to the bag or loss of its contents. In addition, keeping litter bags in place between storms ensures that all the litter is captured.

2.2.4 Completeness

Completeness for chemical data is a measure of the amount of valid data expressed as a percentage obtained from a measurement system compared to the amount that is expected to be obtained under normal conditions. Completeness criteria will focus on the performance of the sampling network. The completeness of the continuous flow measurements is also important. The target completeness criteria for the flow meters will be to produce valid time series data at least 80 percent of the time. The target completeness criteria for spatial coverage will be to have at least 80 percent of the monitoring network locations provide valid synoptic data. At a particular location, the target completeness criterion for temporal coverage during a storm event is to collect samples over at least 80 percent of the storm event hydrograph, sample collection from less than 80 percent of the storm event hydrograph will be considered on a case by case basis.

Litter data is considered complete if all litter is collected as specified in the SOP.

2.2.5 Comparability

Comparability is the confidence with which one data set can be compared to another for chemical and litter data. SOPs for both the field and laboratory will be used to ensure comparability of the data sets. Consistent use of analytical methods and procedures is used to compare chemical data generated.

Section 3
Monitoring Locations

This section describes the overall design of the Water Quality and Litter Monitoring Program sampling network used to conduct Caltrans Drain Inlet Cleaning Efficacy Study 2000-2001 Water Quality and Litter Monitoring Program. Descriptions of the monitoring station selection process, monitoring station locations, and sampling and monitoring equipment are addressed in the following sections.

3.1 Monitoring Station Selection

Monitoring station locations were selected and equipment permanently installed based on the criteria presented below. During the 2000-2001 wet weather season, eight monitoring stations will be used to monitor storm water runoff. When selecting monitoring locations, the criteria below were used to help ensure that the storm water collected during the Monitoring Program will meet the program objectives and satisfy safety requirements during installation, monitoring, and maintenance of the stations. The following monitoring station selection criteria, ranked in order of priority, were used to evaluate all potential monitoring locations.

1. **Personnel Safety.** The number one criterion in selecting a monitoring station was personnel safety. The selected site must offer safe conditions for personnel to work during installation, operations, and maintenance of the monitoring stations. Monitoring stations along freeway shoulders and medians, as well as narrow on and off ramps, were eliminated due to safety concerns. Other safety issues included: site access and extent of confined space entry during installation and maintenance of the monitoring station.

2. **Material Accumulation.** A critical criterion for the initial selection of the monitoring stations was material accumulation. The presence of inlets with heavy material accumulation within each catchment is critical in assessing the effectiveness of the inlet cleaning program and its impact on storm water quality. For the 2000-2001 Monitoring Program, several new sites were selected. Selection was also based on the presence of material accumulation within the drop inlets and for the catchment area.

3. **Drainage Area.** Ideally, the drainage area for each catchment should consist of a minimum of approximately two acres and include a minimum of four drop inlets. Storm water tributary to a monitoring location must originate within the Caltrans freeway system only. Catchment areas with a drainage area encompassing developed portions of a city adjacent to the freeway were excluded. This criterion was essential in limiting the potential for dumping of illegal materials within the catchment areas while concentrating on runoff that originates solely within Caltrans property.

4. **Physical Limitations of Sampling Equipment.** The sampling equipment operates more effectively under certain operating conditions. Sampling limitations include: maximum vertical lift capability and overall sampling distance, flow characteristics and velocities, and outfall diameter and slope. Generally, the maximum vertical lift is limited to 20 to 25 feet, while the maximum sampling distance is generally less than 40 feet. In addition, drainage lines with steep slopes are avoided due to flow and velocity conditions that adversely impact equipment performance.

   Once the sampling equipment requirements were met, additional considerations for placement of the litter collection device were evaluated. These considerations included: at least two acres of Caltrans property would need to drain to the catchment area, at least 4 drain inlets had to be present in the catchment area, and downstream flow placement of the collection device could not impair storm water flow causing backflow conditions.

5. **Backwater Considerations.** The drainage outlet must be located in an area where drainage flows and velocities in the main downstream channel of storm drain do not result in a backflow condition in the vicinity of the monitoring location. Backflow conditions will adversely impact velocity measurements due to turbulent flow, and could compromise sample integrity due to the possible mixing of flows originating from Caltrans property with flows originating from outside Caltrans property boundaries. Backflow conditions are more of a concern with the inclusion of litter sampling into the Monitoring Program. Sites with potential backflow conditions were rejected, both to protect the litter sample and the water quality sample.

6. **Vandalism Potential.** Wherever possible, areas that appear to be subject to vandalism were avoided. Vandalism will result in a much higher maintenance and surveillance program and/or the ultimate destruction of the installation.

7. **Power Access.** Although the stations can be battery operated, the use of electrical utility power significantly increases the overall reliability of the station.

8. **Rain Gauge Installation.** Ideally, precipitation amounts should be recorded at or near the monitoring station. This criterion was introduced due to high spatial variations in cumulative rainfall during storm events.

3.2 Summary of Monitoring Locations

Eight (8) monitoring stations will be operational for the 2000-2001 Monitoring Program. They include stations 21, 22, 23, 24, 26, 27, 28 and 29. The spatial distribution of the monitoring stations is presented in Figure 3-1. A brief summary of the sampling network is presented in Table 3-1. A detailed discussion of the sampling and monitoring equipment installed at each site is presented in the report from a previous study entitled *Summary of Equipment Installation for Caltrans Inlet Water Quality Monitoring* Program prepared by

Woodward-Clyde Consultants for Caltrans on January 6, 1997. Site vicinity maps and site access drawings are provided for each station in the *Caltrans Drain Inlet Cleaning Efficacy Study Water Quality Monitoring Program Health and Safety Plan*.

3.3 Equipment Installation

A detailed description of the sampling and monitoring equipment installed at each monitoring site is provided in the *Summary of Equipment Installation for Caltrans Inlet Water Quality Monitoring Program* report. The following sections briefly describe the equipment that will be utilized for this monitoring program.

3.3.1 Automatic Samplers

The Sigma 900 automatic sampler will be used at all locations. The Sigma 900 sampler provides high lift capability, accurate delivery of sample volumes, high sample line velocity of 3 to 5 feet per second and purge cycle(s) to minimize cross contamination of samples. The Sigma 900 automatic sampler consists of an intake line/strainer, a peristaltic pump, sample containers, and a controller. The samplers will be programmed to collect flow-based composite samples. The intake strainer is attached at the end of the intake line and is securely mounted in the flow. The samplers will be configured with eight, 2-liter polyethylene sample bottles. Either AC or DC electrical power will power the samplers.

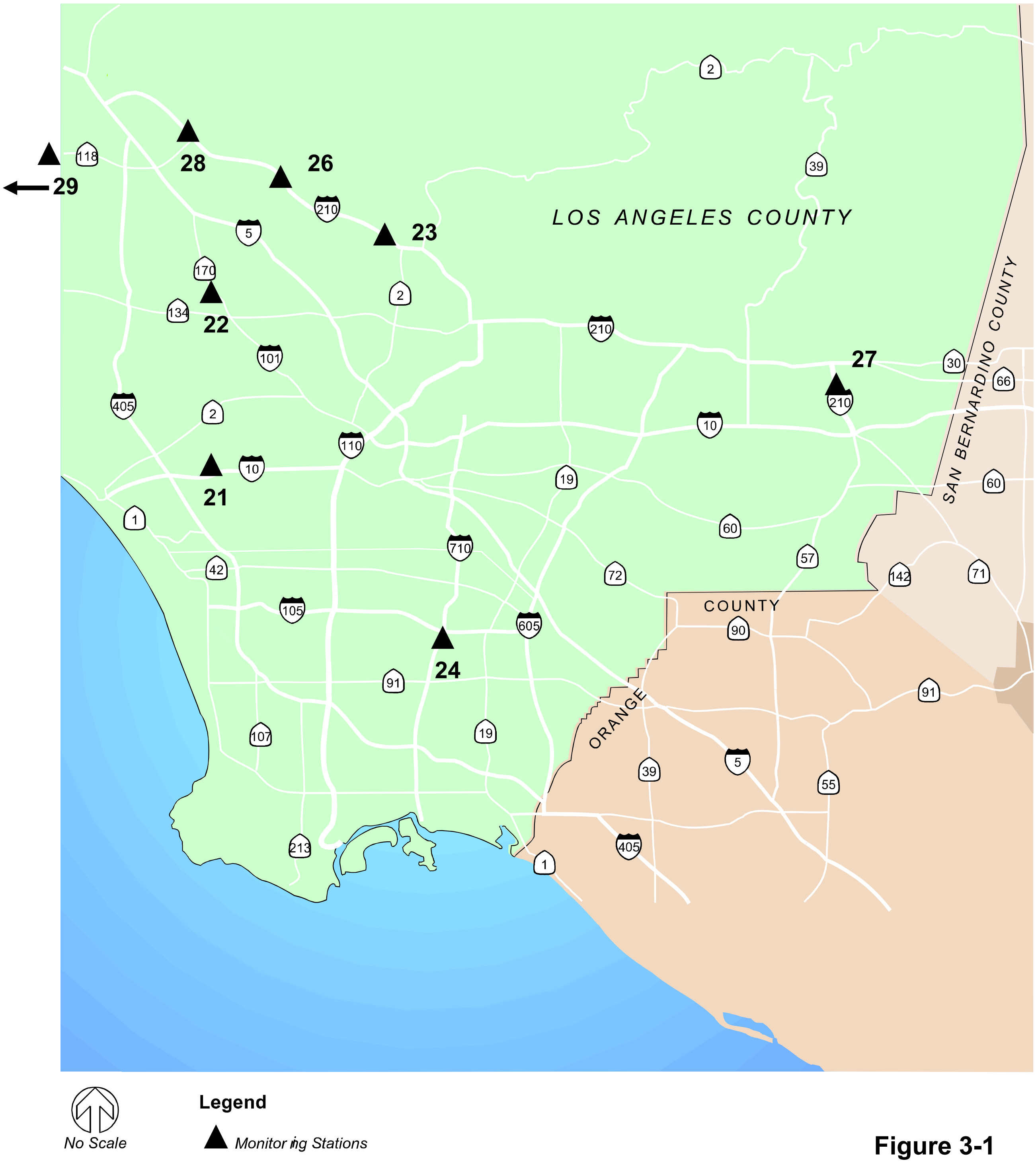


Figure 3-1

Caltrans DICE and Litter Study
Distribution of Monitoring Locations

Table 3-1
Summary of Monitoring Locations

Site Number	Monitoring Location	Freeway/Post Mile	Type of Freeway (Cut/Fill)	Area (Acres)	Number of Drain Inlets	Cleaning Protocol
21	Westbound 10 Freeway at Fairfax off-ramp	10/9.9	Fill	1.2	6	C
22	Northbound 170 Freeway at Oxnard off-ramp	170/16.2	Fill	2.2	7	C
23	Eastbound 210 Freeway at Ocean View on-ramp	210/18.45	Fill	7.0	38	NC
24	Southbound 710 Freeway, south of the 105	710/15.6	Fill	7.2	5	NC
26	Westbound 210 Freeway at Tujunga Wash	210/10.12	Fill	31.1	38	C
27	Westbound 210 Freeway at Gladstone(Auto Center Dr.)	210/44.91	Fill	3.6	10	NC
28	Eastbound 210 Freeway at 118 Interchange	210/6.0	Fill	6.8	6	NC
29	Eastbound 118 Freeway at Topanga Canyon (27)	118/1.6	Fill	2.0	3	C

Notes:
C = Drain inlets will be cleaned
NC = Drain inlets will not be cleaned

Since the samplers will be configured to collect flow weighted samples, a signal will be sent from the flow meter to the sampler after a specified volume of flow (trigger volume) has passed the flow monitoring point. Samples will be collected based on a software routine programmed into the sampler prior to the sampling event. The routine will be designed to collect samples at a frequency and volume that are sufficient to cover the entire sampling event and provide the required sample volume for laboratory analysis. Field crews will retrieve samples after the sampling event has passed. These samples will then be composited at the contracted laboratory. The sampler programming will be reset prior to upcoming rain events based on the projected rainfall distribution.

3.3.2 Flow Meters

Two types of flow meters will be utilized during this monitoring program. The flow meters will be programmed to initiate water quality sampling based on user-selected conditions; generally the exceedance of some predetermined flow volume (trigger volume) at the monitoring location. The following sections briefly describe each of the meters.

Sigma 960 Bubbler

The Sigma 960 Bubbler utilizes the bubbler method of flow measurement. A length of tubing is affixed in the flow stream at the proper location for head measurement. A small amount of air is continuously pushed through the tubing and bubbles slowly out of the end of the tubing. The pressure in the tubing changes in proportion to the liquid level in the flow stream. The Sigma 960 reads this pressure and converts it to a level reading. After a level has been obtained, the flow meter converts the level reading to a flow rate based on the user defined characteristics of the primary device through which the water flows.

Ultrasonic 950 Area Velocity Flow Meter

The ultrasonic 950 area-velocity flow meter utilizes a high frequency (75Khz) sonar-like sensor that is mounted a known distance above the surface of the water (usually at the top conveyance pipe). A transducer emits a sound wave and measures the period of time taken for the wave to travel to the surface of the water and back to the receiver. This time period is converted to a distance and then converted to a depth of flow, based on measurements of the site configuration. Average velocity is measured at the invert of the channel using a wafer thin velocity sensor.

3.3.3 Rain Gauges

Sigma tipping bucket rain gauges will be used to measure and record precipitation amounts. Rain is collected in a standard 8-inch cylinder. Rainfall collected in the cylinder is funneled into the tipping bucket mechanism. The funnel is screened to keep out debris. The bucket tips when a volume equivalent to 0.01 inch of water over the cylinder orifice has accumulated. The bucket tips cause a 0.1-second switch closure, which is recorded by an external datalogger. The tip also brings a second bucket into position under the funnel, ready to fill and repeat the cycle. After the rainwater is measured, it drains out through the base of the gauge. Screens to prevent insect entry cover the drain holes.

3.3.4 Litter Collection Devices

The litter transported to the outfall by storm water will be captured by a thirty inch by forty inch polyester mesh bag with one quarter inch mesh. The storm water, once it has exited the outfall, will be guided into a twenty-four inch PVC pipe. The end of the twenty-four inch PVC pipe will have the mesh bag secured to it with nylon straps, to allow the litter bag to be removed and changed. Slots in the PVC pipe, or a lower section of headwall will provide overflow protection should the litter bag become full and not allow water to flow through. A enclosure will be installed around the mesh litter bag to prevent vandalism, rodents and tampering with the litter sample.

Section 4
Sampling Network and Methods

This section describes the operation of the Caltrans Drain Inlet Cleaning Efficacy Study 2000-2001 Water Quality and Litter Monitoring Program and the sampling methods that will be used during the 2000-2001 wet season.

4.1 Procedures for Estimating Runoff Coefficients and Volumes

The Caltrans Drain Inlet Cleaning Efficacy Study 2000-2001 Water Quality and Litter Monitoring Program will require collection of flow weighted samples. The runoff volume at each site must be estimated to develop a flow weighting scheme that is representative of each monitored storm event. At each monitoring site, the total estimated runoff volume is used to calculate a trigger volume, which is programmed into the flow meter. The flow meter is interfaced with an automatic sampler which is programmed to collect samples after specified flow increments (e.g., every 5,000 gallons collect a 500 ml sample). This section provides a description of procedures for estimating runoff volumes for programming monitoring equipment, and a description of determining actual runoff volumes after the storm has occurred.

Runoff volume is the volume of rainwater that does not infiltrate but runs off over the surface of the ground and into a storm drainage system and/or receiving water. Runoff volume generally depends on the amount of impervious surface within a catchment area (impervious surfaces are areas where infiltration of rainfall cannot take place and surface runoff occurs). For a given catchment area, runoff volumes will vary depending upon the size of the storm, the intensity of the storm, and the antecedent dry period. For example, the runoff volume for a storm with a long antecedent dry period will be smaller than the runoff volume for a storm that takes place after the ground is saturated and when infiltration rates are low.

Runoff volumes are estimated as the product of the forecasted rainfall amount, the catchment area, and the estimated runoff coefficient. A runoff coefficient is defined as the fraction of total rainfall volume (the amount of rainfall over the catchment area) that becomes storm water runoff. Runoff coefficients are initially estimated to be approximately equal to the percent impervious area of the catchment. At five (5) of the 2000-2001 sites, coefficients will be estimated. For the three (3) sites being reused, the runoff coefficients will be based on the average runoff coefficient calculated from the data obtained during the 1996-2000 Monitoring Programs.

Forecasted runoff volumes will be used to estimate the programmed sampling interval for each site during each sampling event. Anticipated runoff volumes will be calculated by the Storm Event Coordinator prior to each storm event based on the projected rainfall volume in the vicinity of each site. After each event, runoff coefficients will be refined based on measured values. Once flow and rain gauge data have been retrieved, actual runoff coefficients and runoff volumes from the storm will be calculated. This will be accomplished as follows:

- Information will be obtained regarding the actual depth of rain that fell during the event using gauge measurements.

- The actual rainfall depth will be multiplied by the catchment area to get a rainfall volume for the catchment area.

- Measured flow data from the monitoring station will be obtained and the total volume of runoff that occurred at the site for the monitored event will be estimated.

- The estimated storm water runoff volume will be divided by the rainfall volume over the catchment to obtain an actual runoff coefficient for the monitored event.

4.2 Drain Inlet Cleaning and Sampling of Materials Removed from Cleaned Catchment Areas

During the 2000-2001 Monitoring Program, drain inlets designated to be cleaned within the four catchment areas will be cleaned on three separate occasions. All drain inlets in these catchment areas will be cleaned using heavy duty industrial vactor trucks.

To obtain representative material samples from each cleaned drain inlet, up to three discrete material samples will be collected from in the inlet prior to initiation of cleaning activities at each drain inlet. All discrete samples collected from all drain inlets within a catchment area will be composited into a single sample and submitted to the contracted laboratory for particle size analysis. A detailed description of these activities is presented in the Drain Inlet Cleaning and Sampling Standard Operating Procedures.

To measure the volume of the material removed from each inlet, the depth of material in the inlet prior to cleaning will be measured. The dimensions of the drain inlet will also be measured. From these measurements, the volume of the material removed will be calculated.

A single vactor truck and crew will be assigned to each catchment area for cleaning. The weight of the materials removed from each catchment will be measured in the following manner:

- The empty (tare) weight of the truck with full fuel will be measured prior to the start of the cleaning operations.

- After all inlets in each catchment area are cleaned, the truck will be re-fueled and re-weighed.

- Subtracting the empty truck weight from the final weight of the truck after cleaning the inlets will provide a total weight of material removed per catchment.

4.3 Operation of the Sampling Network

Operation of the sampling network will involve: activities to prepare for and respond to storm events, routine equipment servicing, cleaning calibration and maintenance, and data collection and handling.

4.3.1 Wet Weather Response

Sampling response to wet weather events will require significant coordination between the SEC, field teams, contracted laboratory, litter laboratory, and weather forecasting service. Typically, up to eight field crew members will be mobilized during wet weather events for a 30 to 72 hour period, depending on the duration and magnitude of the wet weather event. For the Caltrans Drain Inlet Cleaning Efficacy Study Water Quality and Litter Monitoring, the minimum storm event criteria are as follows:

- 0.20 inches of rainfall with a 50 percent probability of rain
- runoff duration is at least four (4) continuous hours
- storm is preceded by 72 hours of dry weather (48 hours antecedent dry period will be acceptable if approved by the Caltrans Project Coordinator

4.3.1.1 Weather Forecasting and Storm Tracking

Weather forecasting is an important aspect of storm water sampling. It will be necessary to obtain the most reliable and up-to-date information on a storm's meteorological characteristics. A contracted weather service, WeatherWatch Service, will be used to provide daily forecasts and climatic information. Information obtained for each forecast will include: the probability of precipitation, the expected amount of precipitation, the storm duration, and the expected arrival time of the precipitation. In addition, forecasts will be obtained on a daily basis from the National Weather Service information phone lines for Los Angeles and vicinity, and radar images of weather patterns for southern California will be routinely downloaded from the Internet. Field crew will be notified within 72 hours of an advancing storm. At this time, the litter laboratory will also be notified.

The SEC will review the forecasts on a daily basis and will decide to mobilize and prepare for a sampling event when a predicted storm meets the storm selection criteria. When a forecast suggests that a storm satisfies the selection criteria, preparation for the sampling event will begin. Storm sampling preparation activities are described in the following section.

4.3.1.2 Preparing for a Sampling Event

Once a decision is made to sample an approaching storm, field sampling personnel will be notified and all necessary sample bottles and litter bags will be collected. Based on the forecast, estimates will also be made of the runoff volume expected at each station. This estimate will be based on the predicted rainfall amount and estimated runoff coefficients (see Section 4.1).

If the updated forecast shows that the storm still satisfies the selection criteria field crews and the litter laboratory will be notified within 24 hours to ready for mobilization. Within 12 hours of the storm's expected arrival, field crews will travel to the sampling sites to prepare samplers and litter bags. Preparing the samplers for the event will include replacing the batteries in the sampler and flow meter (if required), inspecting sampler hoses and electrical connections, inspecting the pump tubing and replacing it if needed, programming the sampler, programming the flow meter, initiating the sampling programs, putting ice into the bottom of the sampler, and recording set-up information on a field data sheet. Preparing the litter bags for the event will include; removing pre-event litter bag, transferring pre-event litter bag to plastic trash bag, labeling pre-event bag, completing field data sheet, and installing a clean litter bag. All personnel will be required to follow pre-storm event procedures as described in detail in the *Pre-Storm Event Standard Operating Procedures of the DICE II - Litter Study SOP and Litter Laboratory Coordination and Sample Delivery Protocol SOP*.

4.3.1.3 Sampling Event

If the SEC calls a sampling event, all personnel will follow the event procedures as described in detail in the SOPs identified above. During the sampling event, the goal is for the automatic sampler to collect a sufficient volume of sample for conducting the desired suite of chemical analyses and to collect a sufficient number of samples to represent the entire hydrograph from the storm event. The required sample volume for the Caltrans Drain Inlet Cleaning Efficacy Study Water Quality and Litter Monitoring Program is shown in Table 7-1.

Once field crews are mobilized in the field, they are to inspect the condition of the sampling station; check the mesh bag for pre-storm litter; if any litter accumulated in the mesh bags before the storm event, then the mesh bags will be removed and replaced with a new mesh bag if necessary; notify the litter lab of the number of pre-storm samples to be delivered; and complete a Pre-Storm Event Activities Form. It is anticipated that this will occur 2 to 12 hours prior to a storm event.

4.3.1.4 Field Observations

Field observations made of the water quality will include notes on color, turbidity, odor, temperature, and floating debris. Field crews will be instructed to document any conditions that may further explain the sampling data.

4.3.2 Data Collection

Data collection from recording equipment, such as flow meters and rain gauges, will be downloaded by the SEC using America Sigma's *Insight* software shortly following each wet weather event. Flow meters and rain gauges will remain on continuously, with data collected following each wet weather event. Data collected in the field and recorded on field data sheets will be submitted by field crews to the SEC after each event. The data will be reviewed by the SEC and prepared for database input.

After the storm event, the field crew will remove mesh bags from the outfall. Water will be drained from the bag, the volume of material in the mesh bag will be estimated, the mesh bag placed in a plastic bag, and a label attached as specified in the SOP. The mesh bag and plastic bag shall then be weighed. A Storm Event Litter collection Field Data Form will be completed and a clean mesh bag placed on each outfall before the field crew leaves the site. The SEC would then inform the litter laboratory that a sample is en route.

4.3.3 Post-Storm Event Summary

Following each sampled storm event, the SEC will draft a post-storm event summary. The post-storm event summary will be based on the field data collected by the field crews. The post-storm event summary will summarize the hydrologic conditions, problems (if any), and field observations experienced at each site, and will be submitted to the Caltrans Project Coordinator within 72 hours.

4.3.4 Laboratory Coordination

To ensure a successful sampling event, the SEC must make sure that the contracted laboratories are kept appraised of all upcoming storm events. In addition, the SEC must coordinate courier service with the laboratory, bottle preparation, and sample compositing, as needed. The laboratory must also be prepared to receive samples as they are collected, regardless of time of day, or day of the week.

The litter laboratory will be informed of sample arrival 72 hours, 24 hours and 2 hours before delivery to the laboratory. Samples will be received in a designated area of the laboratory as defined by the laboratory supervisor. All litter samples must be accompanied with a Chain-of-Custody Form (see SOP). The form should be checked to make sure all information is entered and correct.

4.3.5 Routine Inspection and Maintenance

Routine inspection, maintenance, and calibration of the sampling and monitoring equipment will be required. Litter collection devices will be inspected during routine inspection, maintenance and calibration activities. The SEC will dispatch maintenance crews as needed.

Section 5
Field Documentation

Monitoring activities and results will be documented through field data collection forms, logbooks, visual observations, chain-of-custody forms and analytical reports. This section defines and discusses methods by which the collected sampling data will be organized and presented. These procedures will be performed in conjunction with sample quality assessment identified in Section 2.

5.1 Field Data Collection Forms

Proper documentation of all field activities is essential to ensure that data quality objectives are achieved. The data for this project will include field collected information and analytical sampling. Most field data and record keeping will be documented on standard forms kept in the site notebook. The following forms will be utilized for this monitoring program:

- Sampling Equipment Checklist
- Site Visitation Log
- Station Visit Checklist for Set-up/Bottle Replacement/and Shut-down
- Field Data Log
- Sample Identification Form
- Field Maintenance Log
- Drain Inlet Cleaning and Sampling Checklist

Entries on all field data collection forms will be as descriptive as possible, so that a particular situation can be reconstructed. Entries will be made in pen; no erasures will be permitted. If an incorrect entry is made, the data will be crossed out with a single line and initialed. All field data forms will be on water-resistant paper so entries cannot be affected by moisture.

5.2 Field Notebooks

Each monitoring station will be assigned a field notebook. Copies of all data collection forms will be kept in each monitoring station's field notebook. Field notebooks will be used to store field data collection forms, station programming information, and phone numbers of program participants. The field notebook will never leave the monitoring station. All completed field data forms will be brought/sent to the SEC after each monitored event.

5.3 Chain-of-Custody Forms

Sample chain-of-custody protocols shall be maintained through the receipt of the sample containers, sample collection, transfer between personnel and shipment to the laboratory, and final disposal of the sample. The purpose of the protocols and procedures established in the monitoring plan is to maintain the integrity of the samples, from collection to analysis. The sample custody shall be properly documented to provide a mechanism for tracking each sample submitted for laboratory analysis.

Litter chain-of-custody shall be maintained through the collection of mesh litter bags, transfer between personnel, shipment to the laboratory, and final transfer to laboratory personnel. When a sample arrives at the litter laboratory, sample identifying data is recorded into a bound logbook. A unique laboratory sample identification number is assigned.

Chemical and litter sample custody protocols, field procedures, transfer of custody and shipment are provided below. Samples refer to both chemical and litter samples.

5.3.1 Chain-of-Custody Protocols

The purpose of chain-of-custody procedure is to document the identity of the sample, and its handling. Custody records trace a sample from its collection through all transfers of custody until it is transferred to the analytical laboratory. A sample is considered under a person's custody if it meets the following requirements:

- The sample is in the person's possession
- The sample is in the person's view, after being in the person's possession
- The sample was in the person's possession and it was placed in a secured location
- The sample is in a designated secured area

The sample packaging and shipment procedures summarized below will assure that the samples will arrive at the laboratory with the chain-of-custody intact.

5.3.2 Chain-of-Custody Field Procedures

A separate chain-of-custody form will be completed for chemical and litter analysis. Chain-of-custody field procedures are as follows:

- The field crew member(s) will be personally responsible for the care and custody of the samples until they are transferred or properly dispatched. As few people as possible will handle the samples.

- Sample labels will be filled out using waterproof ink for each sample.

- All bottles and bags will be labeled with sample numbers and locations using appropriate labels and naming scheme as described in the SOPs.

- The samples will be delivered to the appropriate laboratory for analytical and litter work. Quality control samples will be delivered directly by the field staff to the QC laboratory, or will be picked up by the laboratory staff from the field facility. The laboratory QA director will review all field activities to determine whether proper custody procedures were followed during the work and decide if additional samples are required.

5.3.3 Transfer of Custody and Shipment Procedures

Transfer of custody and shipment procedures are as follows:

- A properly completed chain-of-custody form will accompany samples. The sample numbers and locations will be listed on the chain-of-custody form. When transferring the possession of samples, the individuals relinquishing and receiving will sign, date, and note the time on the record. This record documents transfer of custody of samples from the sampler to another person, to/from a secure storage area, and to the laboratory.

- Samples will be properly packaged for shipment and dispatched to the appropriate laboratory for analysis with a signed custody record enclosed in each sample cooler or other transport container.

- The chain-of-custody record identifying the contents will accompany all overnight and field crew delivered shipments. The original record will accompany the shipment/delivery, and the pink and yellow copies will be retained by the sampler for returning to the project files.

5.3.4 Required Information on Chain-of-Custody Forms

The following information will be supplied on the chain-of-custody form:

- Project code number
- Signature of sampler
- Sample identification
- Sample matrix (water or soil)
- Date and time of sample collection
- Signatures of all persons receiving or relinquishing the samples
- Sample analyses required for each sample
- Laboratory QC samples will be identified
- Preservatives used, if applicable
- Number of sample containers

Section 6
Sample Designation

All sample bottles should be pre-labeled on the bottle rather than the cap to identify the sample for laboratory analysis. Sample labels should include type of sample (grab or composite), type of QC sample (i.e. field splits), sampler's name, date, time, and location. Litter samples will also need to be labeled prior to delivery to the laboratory. Sample identification will use the following format:

Bottle Sample Numbering Scheme:

SSYYMMDDHHmmTTT

Where:

SS	=	station number (21-29)
YY	=	last two digits of the year (00 or 01)
MM	=	month (01-12)
DD	=	day (01-31)
HH	=	hour of the sample (00-23)
mm	=	minute of the sample collection (00-59)
TTT	=	type of sample

AT#	=	automatic sampler sample
L#	=	litter sample
EB#	=	equipment blank
DIC#	=	drain inlet cleaning sample
T	=	tray number
#	=	bottle number or litter sample number

Bag Sample Labeling should include:

- Project Name
- Site Name – Highway and Cross Street
- Site Number
- Storm Event Number
- Collection Date and time
- Sample Number
- Collected by

Section 7
Sample Handling, Analytical Methods, and Procedures

This section describes sample handling, analytical methods, and procedures. Methods and procedures will be in accordance with those specified in an EPA or other standard reference.

7.1 Sample Handling

All water samples collected will be placed in the appropriate autosampler bottles, with preservative if necessary, and stored in an ice chest or refrigerator immediately after collection. Double-bagged ice will be placed in the ice chest as well. Litter samples will be placed in heavy-duty contractor garbage bags and labeled for shipment to the laboratory. The samples will be picked up by the analytical laboratory in a timely manner to allow analyses within the required holding times.

7.2 Analytical Methods

7.2.1 Drain Inlet Cleaning Efficacy Study Water Quality and Litter Monitoring Program

Table 7-1 summarizes all of the analytical parameters and EPA method reference numbers for the samples to be collected under the Caltrans Drain Inlet Cleaning Efficacy Study Water Quality and Litter Monitoring Program. Table 7-1 also presents a summary of sample handling requirements including:

- Volume of sample
- Type of sample container
- Preservative
- Holding Time

Field crews must be familiar with and carefully follow these requirements. Failure to do so will invalidate the analytical results.

For analytes with holding times less than 48 hours, composite samples lasting longer than 24 hours require multiple bottle composite samples. If it is determined that the storm event will last longer than 24-hours, the SEC will mobilize the field crews to switch out the bottles before 24 hours of sampling have elapsed. These composite samples will be analyzed by the laboratory for those constituents with holding times less than 48 hours.

7.2.2 Drain Inlet Sediment Sampling

Table 7-2 summarizes the EPA method reference numbers for particle size analysis of the sediment samples collected from the cleaned catchment areas as part of the Caltrans Drain Inlet Cleaning Efficacy Study Water Quality and Litter Monitoring Program. Table 7-2 also presents a summary of sample handling requirements including:

- Mass of sample
- Type of sample container
- Preservative
- Holding Time

Field crews must be familiar with and carefully follow these requirements. Failure to do so will invalidate the analytical results.

Table 7-1
Summary of Analytical Methods, Sample Volumes, Containers, Preservation and Holding Time Requirements
Caltrans Drain Inlet Cleaning Efficacy Study Water Quality Monitoring Program

Parameter	Sampling Method	EPA Analytical Method Number	Target Reporting Limit (mg/L)	Required Volume (mL)	Container	Required Preservative	Holding Times
Metals (Total and Dissolved)							
Arsenic	Flow-based	200.8	0.0005	500 [a]	Poly	HNO_3; pH <2*	6 months
Cadmium	Flow-based	200.8	0.0002				
Chromium	Flow-based	200.8	0.001				
Copper	Flow-based	200.8	0.001				
Lead	Flow-based	200.8	0.001				
Nickel	Flow-based	200.8	0.002				
Zinc	Flow-based	200.8	0.005				
Nutrients							
Dissolved Phosphorus	Flow-based	365.3	0.03	50	Poly	4 ∀ 2EC	28 days
Nitrate-N	Flow-based	300.0	0.10	100	Poly	4 ∀ 2EC	48 hours
TKN	Flow-based	351.3	0.10	500	Poly	H_2SO_4; pH <2*	28 days
Total Phosphorus	Flow-based	365.3	0.03	50	Poly	4 ∀ 2EC	28 days
Dissolved Ortho Phosphate	Flow-based	365.3	0.03	50	Poly	4 ∀ 2EC	48 hours
General							
Temperature			∀ 0.1EC				
Hardness	Flow-based	130.2	2	100	Poly	HNO_3; pH <2*	6 months
pH	Flow-based	150.1	0.1 SU	50	Poly	4 ∀ 2EC	ASAP
Specific Conductivity	Flow-based	120.1	1 umhos/cm	50	Poly	4 ∀ 2EC	28 days
Total Organic Carbon	Flow-based	415.1	1	100	Poly	H_2SO_4; pH <2*	28 days
Dissolved Organic Carbon	Flow-based	415.1	1	100	Poly	H_2SO_4; pH <2*	28 days
Total Suspended Solids	Flow-based	160.2	1	100	Poly	4 ∀ 2EC	7 days
Total Dissolved Solids	Flow-based	160.1	1	100	Poly	4 ∀ 2EC	7 days
Volatile Solids	Flow-based	160.4	1	100	Poly	4 ∀ 2EC	48 hours

[a]All metal analyses may be conducted using the indicated required volume.
mg/L= milligrams per liter
mL= milliliter
*No chemical preservation at time of collection by autosampler, preservation at lab after compositing.

Table 7-2
Summary of Analytical Methods, Required Mass, Containers, Preservation and Holding Time Requirements
Caltrans Drain Inlet Cleaning Efficacy Study Water Quality Monitoring Program
Particle Size Analysis

Parameter	***Sampling Method***	***Method Number***	***Target Detection Limit (mgs/kg)***	***Required Mass (g)***	***Container***	***Required Preservative***	***Holding Times***
Sediment Fractionation							
Particle Size Analysis	Composite	ASTM D422M, D4464	NA	100	NA	NA	NA

mg/kg = milligram per kilogram
g = gram

7.3 Quality Assurance/Quality Control

Several quality assurance and control procedures will be performed to assist in identifying and limiting the introduction of sample contaminants. Quality assurance and control will be the responsibility of the onsite field team leader as specified in Section 1. It is their responsibility to ensure that all field staff are trained and adequately supervised in terms of sample handling procedures. It shall also be their responsibility to ensure that all QA/QC samples are collected. The following text includes separate descriptions for field and laboratory portions of the QA/QC program.

7.3.1 Field QA/QC Procedures

Training

To ensure the accuracy of the data collected, quality assurance/quality control procedures will be implemented during equipment installation and monitoring activities. The responsible party(ies) for setting up and maintaining the monitoring stations will have access to copies of the *DICE II - Litter Study Standard Operating Procedures (SOP)*, as well as hands-on training by qualified personnel in the field prior to the initiation of the sampling program. Training will include details on how to sample, install, program, load and unload the automatic samplers; and downloading of information from data loggers.

Field Split

Split samples will be used to verify the precision of the laboratory analysis. Split samples will be prepared in the field by splitting a volume of sample. Both sample volumes will be delivered blind to the contracted laboratory for identical analysis. Split samples will be prepared for both grab samples and flow-weighted composite samples. Split samples will be prepared and analyzed at a minimum frequency of one per 20 samples collected from each station.

Sample Labels

The laboratory will provide pre-labeled sample containers. The following information will be recorded on each sample container label:

- Sampling date and time
- Sample station identification
- Sequential sample identification number
- Type of sample (automated or grab)
- Identification of preservatives
- Laboratory analysis requested
- Name of individual(s) who collected the sample

7.3.2 Laboratory Quality Assurance/Quality Control

Analytical quality assurance for this program includes the following:

- Employing analytical chemists trained in the procedures to be followed.

- Adherence to documented procedures, EPA methods, written SOPs, and other approved methods (e.g., Standard Methods).
- Calibration of analytical instruments.
- Use of Standard Reference Materials (SRMs).
- Complete documentation of sample tracking and analysis.

Internal laboratory quality control checks will include the use of method blanks, matrix spike/matrix spike duplicates, replicates, laboratory control samples and Standard Reference Materials (SRMs). These QA/QC activities are discussed below and their applicability to each analyte is summarized in Table 7-3. Quality assurance/quality control objectives for storm water samples are summarized in Table 7-4 for each parameter.

Laboratory Duplicates A laboratory duplicate (also called a laboratory split) sample is generated by the laboratory. Laboratory duplicate samples will be prepared and analyzed for specific analytical methods where other QC elements (i.e., MS/MSD or LCS samples) are not required or specified. Duplicate analyses results are evaluated by calculating the relative percent difference (RPD) between the two sets of results. This serves as a measure of the reproducibility (precision) of the sample results. Typically, duplicate results will fall within an accepted RPD range, depending upon the analysis (see Table 7-4).

Method Blanks On a frequency of one per batch of 20 or fewer samples, a method blank sample will be analyzed for each analytical method. A method blank is a sample of a known matrix that has been subjected to the same complete analytical procedure as the submitted samples to determine if potential contamination has been introduced into the samples during processing. Blank analysis results will be checked against reporting limits for that analyte. Results should be less than the reporting limits for each analyte.

Spikes Two different kinds of spikes will be used: matrix spikes (MS) and laboratory control (blank) spikes (LCS).

Matrix spikes involve adding a known amount of the analyte(s) of interest to one of the submitted samples being analyzed. One sample is split into three separate portions. One portion is analyzed to determine the concentration of the analyte(s) in question in an unspiked state. The other two portions are spiked with a known concentration of the analyte(s) of interest. The recovery of the spiked samples is a measure of the accuracy of the analysis. By determining MSD recoveries, another measure of precision (RPD) can be calculated. Both the RPD values and spike recoveries are compared against accepted and known method-dependent limits. Results outside these limits are subject to corrective action. MS/MSD data are also useful in evaluating matrix interference.

The second spike type, the LCS, involves spiking known amounts of the analyte(s) of interest into a known, clean matrix to assess laboratory performance of the method and the possible matrix effects on spike recoveries. High or low recoveries of the analytes in the matrix spikes may be caused by interferences in the sample. LCSs assess these possible matrix effects because the matrix is known to be free from interferences. Matrix spikes and

LCSs are analyzed at a frequency of one per batch of 20 or fewer samples for specific methods

Standard Reference Materials (SRMs) A SRM is a sample containing a known and certified amount of the analyte of interest and is typically analyzed by personnel without the knowledge of that concentration. SRMs are typically purchased from independent suppliers who prepare them and certify the analyte concentrations. Results are evaluated by comparing results obtained against the known quantity and the acceptable range of results supplied by the manufacturer. The laboratory will analyze one external reference standard appropriate to the sample matrix at least quarterly. Results of this analysis will be provided to the Task Order Manager.

Corrective Action Corrective action is taken when an analysis is deemed unreasonable for some reason. These reasons include exceeding RPD ranges and/or problems with spike recoveries or blanks. The corrective action varies somewhat from analysis to analysis, but typically involves the following:

- A check of procedures
- A review of documents and calculations to identify possible errors
- Correction of errors
- Similar calculations to improve accuracy
- A re-analysis of the sample extract, if available, to determine if results can be improved
- A complete reprocessing and re-analysis of additional sample material, if available and if the holding time has not been exceeded

Litter quality assurance for this program includes the following:

- Capturing 100 percent of litter
- Maintaining sample integrity
- Employing standardized methods
- Consistent sample handling and custody procedures
- Use proper sampling techniques
- Use appropriate sample containers

Table 7-3
Laboratory Quality Control Samples by Analyte

Parameter	*Blanks*[1]	*Duplicates*[2]	*MS/MSDs*[3]	*LCS*[4]	*SRMs*[5]
Hardness	✓	✓	–	–	✓
TDS	–	✓	–	–	–
TSS	–	✓	–	–	–
Total Organic Carbon	✓	–	✓	✓	✓
Dissolved Organic Carbon	✓	–	✓	✓	✓
Volatile Solids	–	✓	–	–	–
Specific Conductivity	–	✓	–	–	✓
pH	–	✓	–	–	–
TKN	✓	✓	–	–	✓
Nitrate	✓	–	✓	✓	✓
Total Phosphorus	✓	–	✓	✓	✓
Dissolved Phosphorus	✓	–	✓	✓	✓
Dissolved Ortho-phosphate	✓	–	✓	✓	✓
Total and Dissolved Metals	✓	–	✓[6]	✓[6]	✓

(1) Equipment and Method Blanks.
(2) Analytes are for laboratory (not field) duplicates.
(3) Matrix Spike/Matrix Spike Duplicates
(4) Laboratory Control Sample
(5) Standard Reference Materials
(6) Total metals only

Table 7-4 *Storm Water Matrix* *Quality Assurance/Quality Control Objectives*						
Parameter	***Reporting Limits***	***Accuracy***		***Precision***		***Completenes***
		MS/MSD(1) Recovery	LCS(2) Recovery	Matrix Spike RPDs(3)	Duplicate RPDs	
Conventionals						
Hardness	2 mg/L	-	-	-	<20%	95%
TDS	1 mg/L	-	-	-	<20%	95%
TSS	1 mg/L	-	-	-	<20%	95%
Total Organic Carbon	1 mg/L	85%-115%	85%-115%	<15%	-	95%
Dissolved Organic Carbon	1 mg/L	85%-115%	85%-115%	<15%	-	95%
Volatile Solids	1 mg/L	-	-	-	<20%	95%
Specific Conductivity	1.0 µmhos/cm	-	-	-	<20%	95%
pH	0.01 units	-	-	-	<20%	95%
Nutrients						
Ammonia	0.1 mg/L	-	-	-	<20%	95%
TKN	0.3 mg/L	-	-	-	<20%	95%
Nitrate	0.1 mg/L	80%-120%	80%-120%	<20%	-	95%
Nitrite	0.1 mg/L	80%-120%	80%-120%	<20%	-	95%
Total Phosphorus	0.03 mg/L	80%-120%	80%-120%	<20%	-	95%
Dissolved Phosphorus	0.03 mg/L	80%-120%	80%-120%	<20%	-	95%
Dissolved Ortho-phosphate	0.03 mg/L	80%-120%	80%-120%	<20%	-	95%
Metals (Total and Dissolved)						
Arsenic	0.5 µg/L	75%-125%	80%-120%	<20%	--	95%
Cadmium	0.2 µg/L	75%-125%	80%-120%	<20%	--	95%
Chromium	1 µg/L	75%-125%	80%-120%	<20%	--	95%
Copper	1 µg/L	75%-125%	80%-120%	<20%	--	95%
Lead	1 µg/L	75%-125%	80%-120%	<20%	--	95%
Nickel	2 µg/L	75%-125%	80%-120%	<20%	--	95%
Zinc	5 µg/L	75%-125%	80%-120%	<20%	--	95%

(1) Matrix Spike/Matrix Spike Duplicates
(2) Laboratory Control Sample
(3) Relative Percent Differences

Section 8
Data Analysis

A critical component of this Monitoring Program is effectively utilizing the collected data to assess and determine:

- Event mean concentrations (EMCs) of each target parameter for each monitoring station,
- Characteristics of the materials removed during the cleaning process for each cleaned catchment area,
- Differences between water quality data collected from catchment areas which were cleaned and data collected from catchment areas which were not cleaned,
- Comparisons of the particle size fractionation between materials removed during the drain inlet cleaning process and materials present in storm water discharges from the catchment areas,
- Data gaps and refinements to the program that will improve the overall study

During the sixth year of the program (2001-2002), the cleaned and uncleaned catchment areas will be switched which will allow analyses of temporal (year to year) differences in addition to spatial (cleaned vs. uncleaned) differences. Moreover, switching the cleaned and uncleaned catchment areas will help to remove bias from the data sets. Where possible, the data analyses will be designed to minimize uncertainty and eliminate sources of bias in the results.

This section provides an overview of the type of data analysis and statistical methods, which will be considered to evaluate the collected data. The actual data analyses will be based on the amount of data collected (degrees of freedom) and the characteristics of the data (normal vs. not-normal distribution).

8.1 Event Mean Concentrations (EMCs)

For each monitoring station storm event, an EMC will be estimated by the laboratory analyses of a flow- weighted composite sample for each parameter. Where sufficient sample volume is available, the laboratory will also analyze up to eight discrete samples for total suspended solids. The results of these discrete samples will be mathematically composited using the storm event hydrograph information as a check on the flow-weighted composite sample.

8.2 Summary Statistics

Summary statistics will be generated for individual storm events and for the cumulative storm season. Event-based and seasonal statistics will be based on pooled data where all sites are grouped according to cleaning protocol. Specifically, all EMCs calculated for each "cleaned" monitoring station will be pooled into a single data set. Likewise, all EMCs calculated for each "uncleaned" monitoring station will be pooled into a single data set. For each of the pooled data sets, the following summary statistics will include:

- Mean
- Median
- Mode
- Standard deviation
- Sample variance
- Skewness
- Maximum concentration
- Minimum concentration
- Number of data points

Litter sample data will be pooled into "cleaned" and "uncleaned" monitoring stations. Particle fractionation information and litter type (vegetative and non-vegetative) percentages will be averaged per monitoring station.

8.3 Statistical Methods

The Caltrans Drain Inlet Cleaning Efficacy Study Water Quality and Litter Monitoring Program will generate two independent groups of data (data from monitoring stations where the drain inlets were cleaned and data from monitoring sites where the drain inlets were not cleaned). The objective of the statistical analyses will be to compare whether EMCs and litter information from one data set are statistically higher or lower than the other is. Box & whisker plots will be prepared for selected constituents to graphically compare the distributions of pooled data sets. If the data does not approximate a normal or lognormal distribution, nonparametric statistics will be applied to analyze the two groups of data. The Wilcoxon Rank-Sum test is a nonparametric test, which allows comparisons between two data sets and makes no assumptions about how the data are distributed. In addition, the pooled data sets do not have to contain a similar number of data points in order to make statistical inferences. The null hypothesis that will be tested is that one group of data is not significantly higher or lower then the other group of data. The appropriate statistical test will be performed to determine if the null hypothesis can be rejected at a given confidence level. Prior to application of the hypothesis tests, several tests will be performed to evaluate whether: 1) the data in each pooled set are normally distributed and 2) the variance or spread of each data set is not significantly different.

Table B-1

Summary of the 1996-1997 Storm Water Analytical Results

Parameter	Cleaned Catchments				Uncleaned Catchments			
	Number	Mean	Max.	Min.	Number	Mean	Max.	Min.
TSS	11	101	285	17	17	81	195	20
TVS	11	36	66	18	17	37	84	14
TOC	11	7.0	13.3	2.1	17	7.8	13.4	2.8
Nitrate	11	0.5	0.7	0.3	17	0.8	2.1	0.3
TKN	11	1.1	2.4	0.6	17	1.3	3.4	<0.5
Total Phosphorous	11	0.2	0.5	<0.1	17	0.3	1.0	<0.1
Dissolved Phosphorous	11	<0.1	<0.1	<0.1	17	0.1	0.6	<0.1
Hardness	11	70	110	26	17	72	260	5
SC	11	71	312	32	17	51	103	28
Cd, total	11	0.001	0.002	<0.001	17	0.001	0.003	<0.001
Cd, dissolved	10	<0.001	<0.001	<0.001	17	<0.001	<0.001	<0.001
Cr, total	11	0.009	0.025	0.004	17	0.007	0.019	0.002
Cr, dissolved	11	0.003	0.004	<0.001	17	0.003	0.004	<0.001
Cu, total	11	0.039	0.106	0.009	17	0.029	0.075	0.006
Cu, dissolved	11	0.024	0.076	0.005	17	0.018	0.034	<0.009
Ni, total	11	0.008	0.018	0.002	17	0.005	0.014	<0.001
Ni, dissolved	11	0.003	0.009	<0.001	17	0.002	0.004	<0.001
Pb, total	11	0.069	0.128	0.029	17	0.042	0.132	0.009
Pb, dissolved	11	0.019	0.042	0.002	17	0.010	0.042	<0.001
Zn, total	11	0.146	0.353	0.061	17	0.139	0.350	0.033
Zn, dissolved	11	0.059	0.122	0.024	17	0.046	0.085	0.002

Notes:

All data expressed as concentrations, mg/L

For concentrations less than the method detection limit, values expressed as one half the detection limit

Table B-2
Summary of the 1997-1998 Storm Water Analytical Results

Parameter	Cleaned Catchments				Uncleaned Catchments			
	Number	Mean	Max.	Min.	Number	Mean	Max.	Min.
TSS	59	88	983	5	65	154	1230	12
TVS	35	42	106	5	34	54	136	13
TOC	59	6.7	45.6	1.5	65	7.7	50.6	1.6
Nitrate	17	1.0	3.6	0.2	18	0.9	3.3	0.2
TKN	59	1.9	57.0	0.3	65	1.1	11.3	0.2
Total Phosphorous	58	0.12	1.20	0.01	65	0.13	0.55	0.02
Dissolved Phosphorous	57	0.03	0.20	0.02	65	0.04	0.34	0.01
Hardness	59	38	365	2	64	56	263	12
SC	59	85	458	19	63	128	644	29
Cd, total	59	0.0010	0.0130	0.0001	65	0.0009	0.0071	0.0001
Cd, dissolved	59	0.0003	0.0031	0.0	65	0.0004	0.0061	0.0
Cr, total	59	0.0066	0.1000	0.0003	65	0.0086	0.0570	0.0005
Cr, dissolved	59	0.0019	0.0052	0.0003	65	0.0023	0.0100	0.0004
Cu, total	59	0.0375	0.7700	0.0017	65	0.0364	0.2800	0.0011
Cu, dissolved	59	0.0089	0.0400	0.0009	65	0.0094	0.0760	0.0009
Ni, total	59	0.0079	0.1300	0.0005	65	0.0103	0.0610	0.0007
Ni, dissolved	59	0.0021	0.0003	0.0100	65	0.0032	0.0250	0.0004
Pb, total	59	0.0576	0.7000	0.0032	65	0.0918	0.6900	0.0006
Pb, dissolved	59	0.0051	0.0410	0.0002	65	0.0080	0.0840	0.0002
Zn, total	59	0.172	2.400	0.021	65	0.198	1.400	0.006
Zn, dissolved	59	0.101	0.720	0.021	65	0.106	0.330	0.018

Notes:

All data expressed as concentrations, mg/L

For concentrations less than the method detection limit, values expressed as one half the detection limit

Table B-3
Summary of the 1998-1999 Storm Water Analytical Results

		Cleaned Catchments				Uncleaned Catchments			
Constituent	**Units**	**Number**	**Mean**	**Maximum**	**Minimum**	**Number**	**Mean**	**Maximum**	**Minimum**
METALS									
Cadmium, Dissolved	µg/L	28	0.231	1	0.03	24	0.301	1	0.02
Cadmium, Total	µg/L	28	0.977	3.1	0.1	24	0.983	3	0.2
Chromium, Dissolved	µg/L	28	3.0	15	1	24	2.9	6	1
Chromium, Total	µg/L	28	12.9	39	3	24	9.9	25	4
Copper, Dissolved	µg/L	28	14.6	24	6	24	17.9	41	9
Copper, Total	µg/L	28	46.9	133	15	24	45.7	135	18
Nickel, Dissolved	µg/L	28	3.8	20	1	24	4.3	14	2
Nickel, Total	µg/L	28	11.8	33	2	24	10.1	30	3
Lead, Dissolved	µg/L	28	3.6	42	0.2	24	4.7	29	0.5
Lead, Total	µg/L	28	110	473	6	24	79.7	285	18
Zinc, Dissolved	µg/L	28	43.5	153	11	24	63.6	190	21
Zinc, Total	µg/L	28	236	740	63	24	161	464	56
NUTRIENTS/CONVENTIONAL CONSTITUENTS									
Hardness	mg/L	28	64.4	160	22	24	48.9	92	22
Nitrate (as N)	mg/L	27	1.2	2.4	0.5	24	1.1	2.5	0.5
pH	Units	27	7.63	9.24	6.77	24	7.36	7.87	6.63
Phosphorus, Dissolved	mg/L	21	0.18	0.3	0.09	24	0.16	0.4	0.07
Phosphorus, Total	mg/L	27	0.27	0.85	0.1	24	0.25	0.5	0.1
EC	umhos/cm	21	147	386	71	24	100	199	50
TKN	mg/L	26	2.25	4.5	0.5	24	2.26	4.8	0.5
TOC	mg/L	27	15	34	0.6	24	15	42	5.7
TSS	mg/L	26	122.4	410	11	24	91.0	276	16
TVS	mg/L	21	60.9	130	18	24	56.9	126	12

Notes:

Mean concentrations were calculated using one half the reporting limit if the results was flagged non-detect . One half the reported value was used if the result was flagged as non-detect due to blank contamination (UB). If the results was flagged as detected below the reporting limit (J), then the reported value was applied to the mean calculation.

Table B-4
Summary of the 1999-2000 Storm Water Analytical Results

		Cleaned Catchments				Uncleaned Catchments			
Constituent	**Units**	**Number**	**Mean**	**Max**	**Min**	**Number**	**Mean**	**Max**	**Min**
METALS									
Cadmium, Dissolved	µg/L	35	0.509	0.7	0.5	33	0.506	0.7	0.5
Cadmium, Total	µg/L	35	1.137	4.5	0.5	33	1.053	3.7	0.5
Chromium, Dissolved	µg/L	35	2.1	4	1	33	2.2	5	1
Chromium, Total	µg/L	35	6.7	28	2	33	8.4	28	3
Copper, Dissolved	µg/L	35	11.8	55	3	33	10.2	50	3
Copper, Total	µg/L	35	32.4	214	13	33	31.6	140	4
Nickel, Dissolved	µg/L	35	2.5	14	1	33	4.5	36	1
Nickel, Total	µg/L	35	7.5	39	2	33	9.4	175	2
Lead, Dissolved	µg/L	35	3.3	10	1	33	4.9	22	1
Lead, Total	µg/L	35	50	362	11	33	99.7	355	9
Zinc, Dissolved	µg/L	35	38.2	159	9	33	36.1	204	8
Zinc, Total	µg/L	35	174	865	57	33	206	564	74
NUTRIENTS/CONVENTIONAL CONSTITUENTS									
Hardness	mg/L	35	34.9	119	15	33	58.7	448	26
Nitrate (as N)	mg/L	31	0.7	4.0	0.19	29	0.9	2.7	0.32
Phosphorus, Dissolved	mg/L	35	0.17	0.81	0.1	33	0.22	0.74	0.1
Phosphorus, Total	mg/L	35	0.24	0.92	0.1	33	0.32	0.82	0.1
EC	umhos/cm	35	78	273	32	34	145	923	59
TKN	mg/L	35	1.53	7	0.6	33	1.89	6.2	0.8
TOC	mg/L	35	10	51	3	33	14	48.5	4.8
TSS	mg/L	35	72.2	606	10	33	95.5	527	14
TVS	mg/L	35	30.4	152	1	33	49.0	128	1

Notes:

Mean concentrations were calculated using one half the reporting limit if the result was flagged non-detect . One half the reported value was used if the result was flagged as non-detect due to blank contamination (UB). If the result was flagged as detected below the reporting limit (J), then the reported value was applied to the mean calculation.

Table B-5
Summary of the 2000 - 2001 Storm Water Analytical Results

		Cleaned Catchments				Uncleaned Catchments			
Parameter	**Reporting Limit**	**Number**	**Mean[1]**	**Max**	**Min**	**Number**	**Mean[1]**	**Max**	**Min**
Conventionals									
pH	0.01pH units	14	7	7.6	6	16	7.1	7.7	6.7
Water Temp.	0.1 ^{o}C	NA	NA	NA	NA	NA	NA	NA	NA
Conductivity	1 umhos/cm	14	73	252	18	16	88	266	40
TSS	1 mg/L	14	48	92	20	16	35	80	9
TVS	1 mg/L	14	48	274	16	16	29	52	6
TDS	1 mg/L	10	87	170	17	14	80	207	17
Hardness	2 mg/L	14	44	142	12	16	44	168	12
DOC	1 mg/L	14	7.9	18.4	2	16	8.4	21	2.8
TOC	1 mg/L	14	7.2	19.8	1.6	16	7.8	22.5	2.9
Nutrients									
Nitrate as N	0.1 mg/L	12	0.84	1.9	0.27	15	0.89	2.8	0.34
Total Nitrogen	0.1 mg/L	14	1.32	4.2	0.4	16	1.48	3.3	0.61
TKN	0.1 mg/L	14	0.67	2.9	0.1	16	0.56	2.1	0.1
Total Phosphorus	0.03 mg/L	14	0.23	0.43	0.14	16	0.25	0.68	0.12
Dissolved Phosphorus	0.03 mg/L	10	0.14	0.35	0.03	13	0.15	0.37	0.05
Dissolved Orthophosphate	0.03 mg/L	12	0.08	0.14	0.03	15	0.08	0.14	0.03
Total Metals									
Arsenic	0.5 µg/L	14	0.79	3.42	0.5	16	1.23	2.85	0.5
Cadmium	0.2 µg/L	14	0.67	1.45	0.23	16	0.51	0.83	0.25
Chromium	1 µg/L	14	5.72	8.64	3.3	16	5.59	9.13	2.99
Copper	1 µg/L	14	24	59.5	12.4	16	24.1	65	12.3
Lead	1 µg/L	14	14.9	113	4.88	16	19	57.9	6.59
Nickel	2 µg/L	14	6.69	23.7	2.88	16	4.63	7.8	2.17
Zinc	5 µg/L	14	161	381	72	16	124	230	50

Table B-5

Summary of the 2000 - 2001 Storm Water Analytical Results

		Cleaned Catchments				Uncleaned Catchments			
Parameter	**Reporting Limit**	**Number**	**Mean[1]**	**Max**	**Min**	**Number**	**Mean[1]**	**Max**	**Min**
Dissolved Metals									
Arsenic	0.5 µg/L	14	0.59	2.44	0.5	16	1.18	2.82	0.5
Cadmium	0.2 µg/L	14	0.29	0.67	0.2	16	0.26	0.51	0.2
Chromium	1 µg/L	14	1.67	2.64	1	16	2.21	3.64	1
Copper	1 µg/L	14	11.7	35	5.6	16	12.5	34.6	5.4
Lead	1 µg/L	14	2.12	6.4	1	16	2.9	29.6	1
Nickel	2 µg/L	14	3.05	6.23	2	16	2.57	4.5	2
Zinc	5 µg/L	14	58	114	28	16	55	155	25

Notes

[1] Mean concentrations were calculated using one half the reporting limit if the results was flagged non-detect. One half the reported value was used if the result was flagged as non-detect due to blank contamination (UB). If the result was flagged as detected below the reporting limit (J), then the reported value was applied to the mean calculation. This method is consistent with method applied during the previous four monitoring seasons.

NA - not available

Table C-1
Descriptive Statistics and Comparison Test Results for Analysis of the 1997-98 Metals Dataset

Category	Parameter	Cadmium (mg/L)		Chromium (mg/L)		Copper (mg/L)		Nickel (mg/L)		Lead (mg/L)		Zinc (mg/L)	
		Cleaned	Uncleaned	Cleaned	Uncleaned	Cleaned	Uncleaned	Cleaned	Uncleaned	Cleaned	Uncleaned	Cleaned	Uncleaned
1997-1998 Data													
Total Metals	N of cases	59	65	59	65	59	65	59	65	59	65	59	65
	Minimum	0	0	0	0.001	0.002	0.001	0	0.001	0.003	0.001	0.021	0.005
	Maximum	0.013	0.007	0.1	0.057	0.77	0.28	0.13	0.061	0.7	0.69	2.4	1.4
	Median	0.001	0.001	0.004	0.005	0.017	0.021	0.004	0.008	0.03	0.05	0.11	0.12
	Mean [1]	0.0006	0.0007	0.0037	0.0054	0.0380	0.0360	0.0043	0.0068	0.0342	0.0447	0.1156	0.1404
	Standard Dev [2]	2.2796	2.0730	2.7539	2.5909	0.0990	0.0440	2.7264	2.5269	2.6039	3.6510	2.1340	2.3187
	Distribution	Ln Normal	Ln Normal	Ln Normal	Ln Normal	Ln Normal	Neither	Ln Normal	Ln Normal	Ln Normal	Ln Normal	Ln Normal	Ln Normal
	Test	t-test on Ln Results		t-test on Ln Results		t-test on Ranked Results		t-test on Ln Results		t-test on Ln Results		t-test on Ln Results	
	p-value	0.34		0.03		0.24		0.01		0.19		0.18	
	p-value (Dunn-Sidak)	1.00		0.50		1.00		0.19		0.99		0.98	
	p-value (Bonferroni)	1.00		0.68		1.00		0.21		1.00		1.00	
	Significant Difference	No		No		No		No		No		No	
Dissolved Metals	N of cases	59	65	59	65	59	65	59	65	59	65	59	65
	Minimum	0	0	0	0	0.001	0.001	0	0	0	0	0.021	0.018
	Maximum	0.003	0.006	0.005	0.01	0.04	0.076	0.01	0.025	0.041	0.084	0.72	0.33
	Median	0	0	0.002	0.002	0.007	0.007	0.002	0.002	0.003	0.004	0.087	0.1
	Mean [1]	0.0002	0.0002	0.0020	0.0020	0.0064	0.0067	0.0015	0.0021	0.0026	0.0031	0.0828	0.0945
	Standard Dev [2]	2.1234	2.3632	0.0010	0.0020	2.3655	2.3210	2.3048	2.4670	3.0374	3.8305	1.8130	1.6803
	Distribution	Ln Normal	Ln Normal	Neither	Normal	Ln Normal	Ln Normal	Ln Normal	Ln Normal	Ln Normal	Ln Normal	Ln Normal	Ln Normal
	Test	t-test on Ln Results		t-test on Ranked Results		t-test on Ln Results		t-test on Ln Results		t-test on Ln Results		t-test on Ln Results	
	p-value	0.91		0.28		0.82		0.03		0.45		0.19	
	p-value (Dunn-Sidak)	1.00		1.00		1.00		0.50		1.00		0.99	
	p-value (Bonferroni)	1.00		1.00		1.00		0.69		1.00		1.00	
	Significant Difference	No		No		No		No		No		No	

[1] Geometric Mean if distribution is Ln Normal
[2] Geometric Standard Deviation if distribution is Ln Normal

Table C-1 (cont.)
Descriptive Statistics and Comparison Test Results for Analysis of the 1997-98 Water Quality Parameter Dataset

		Hardness (mg/L)		Total-N (mg/L)		Dissolved-P (mg/L)		Total-P (mg/L)		Specific Conductivity (uhms/cm2)	
Category	**Parameter**	**Cleaned**	**Uncleaned**	**Cleaned**	**Uncleaned**	**Cleaned**	**Uncleaned**	**Cleaned**	**Uncleaned**	**Cleaned**	**Uncleaned**
1997-1998 Data											
Water Quality	N of cases	59	64	17	18	57	65	58	65	59	63
	Minimum	1.65	12.1	0.22	0.24	0.02	0.008	0.014	0.017	19.3	28.5
	Maximum	365	263	3.6	3.3	0.2	0.34	1.2	0.55	458	644
	Median	22.2	31.7	0.55	0.625	0.025	0.025	0.027	0.073	58.9	79.2
	Mean [1]	37.9860	55.9980	0.6907	0.6643	0.0350	0.0380	0.1220	0.1310	65.7592	93.4101
	Standard Dev [2]	50.9920	55.8090	2.3303	2.2367	0.0330	0.0460	0.2360	0.1360	1.9778	2.0401
	Distribution	Ln Normal	Neither	Ln Normal	Ln Normal	Neither	Neither	Neither	Neither	Ln Normal	Ln Normal
	Test	t-test on Ranked Results		t-test on Ln Results		t-test on Ranked Results		t-test on Ranked Results		t-test on Ln Results	
	p-value	0.001		0.89		0.42		0.006		0.006	
	p-value (Dunn-Sidak)	0.02		1.00		1.00		0.12		0.13	
	p-value (Bonferroni)	0.02		1.00		1.00		0.13		0.13	
	Significant Difference	**Yes**		No		No		No		No	

		Total Suspended Solids (mg/L)		Total Kjeldahl Nitrogen (mg/L)		Total Organic Carbon (mg/L)		Total Volatile Solids (mg/L)	
	Parameter	**Cleaned**	**Uncleaned**	**Cleaned**	**Uncleaned**	**Cleaned**	**Uncleaned**	**Cleaned**	**Uncleaned**
	N of cases	59	65	59	65	59	65	35	34
	Minimum	5	12	0.25	0.17	1.5	1.6	5	13
	Maximum	983	1230	57	11.3	45.6	50.6	106	136
	Median	46	72	0.51	0.72	4.9	6	25	42
	Mean [1]	49.3037	83.6800	1.9460	1.1380	6.7440	7.6920	30.4169	43.9477
	Standard Dev [2]	2.9271	2.8519	7.3690	1.6330	6.9200	7.1200	2.3303	1.9406
	Distribution	Ln Normal	Ln Normal	Neither	Neither	Ln Normal	Neither	Ln Normal	Ln Normal
	Test	t-test on Ln Results		t-test on Ranked Results		t-test on Ranked Results		t-test on Ln Results	
	p-value	0.006		0.54		0.09		0.04	
	p-value (Dunn-Sidak)	0.13		1.00		0.86		0.54	
	p-value (Bonferroni)	0.14		1.00		1.00		0.76	
	Significant Difference	No		No		No		No	

[1] Geometric Mean if distribution is Ln Normal
[2] Geometric Standard Deviation if distribution is Ln Normal

Table C-2 Descriptive Statistics and Comparison Test Results for Analysis of the 1998-99 Metals Dataset													
		Cadmium (µg/L)		***Chromium (µg/L)***		***Copper (µg/L)***		***Nickel (µg/L)***		***Lead (µg/L)***		***Zinc (µg/L)***	
Category	***Parameter***	***Cleaned***	***Uncleaned***	***Cleaned***	***Uncleaned***	***Cleaned***	***Uncleaned***	***Cleaned***	***Uncleaned***	***Cleaned***	***Uncleaned***	***Cleaned***	***Uncleaned***
1998-1999 Data													
Total Metals	N of cases	28	24	28	24	28	24	28	24	28	24	28	24
	Minimum	0.1	0.2	3	4	15	18	2	3	6	18	63	56
	Maximum	3.1	3.0	39	25	133	135	33	30	473	285	740	464
	Median	1.0	1.0	9	8	34	35	10	8	34	56	181	128
	Mean [1]	#REF!	1.0	13	9	47	46	#REF!	#REF!	110	#REF!	#REF!	#REF!
	Standard Dev [2]	#REF!	0.7	9	2	33	31	#REF!	#REF!	132	#REF!	#REF!	#REF!
	Distribution	ln Normal	Neither	Neither	ln Normal	Neither	Neither	ln Normal	ln Normal	Neither	ln Normal	ln Normal	ln Normal
	Test	t-test on ranked data		t-test on ranked data		t-test on ranked data		t-test on Ln data		t-test on ranked data		t-test on ln data	
	p-value	0.65		1.00		0.91		0.34		0.33		0.08	
	p-value (Dunn-Sidak)	1.00		1.00		1.00		1.00		1.00		0.83	
	p-value (Bonferroni)	1.00		1.00		1.00		1.00		1.00		1.00	
	Significant Difference	No		No		No		No		No		No	
Dissolved Metals	N of cases	28	24	28	24	28	24	28	24	28	24	28	24
	Minimum	0.03	0.02	1	1	6	9	1	2	0.2	0.5	11	21
	Maximum	1	1	15	6	24	41	20	14	42	29	153	190
	Median	0.35	0.30	2	3	14	14	5	3	0.8	2	31	51
	Mean [1]	0.42	0.38	3	3	15	18	4	4	3.7	5	#REF!	53
	Standard Dev [2]	0.38	0.36	3	1	5	10	3	3	8.4	7	#REF!	2
	Distribution	Neither	Neither	Neither	Normal	Normal	Neither	Neither	Neither	Neither	Neither	ln Normal	ln Normal
	Test	t-test on ranked data		t-test on ranked data		t-test on ranked data		t-test on ranked data		t-test on ranked data		t-test on ln data	
	p-value	0.69		0.97		1.00		0.29		0.02		0.02	
	p-value (Dunn-Sidak)	1.00		1.00		1.00		1.00		0.29		0.39	
	p-value (Bonferroni)	1.00		1.00		1.00		1.00		0.34		0.49	
	Significant Difference	No		No		No		No		No		No	

[1] Geometric Mean if distribution is ln Normal

[2] Geometric Standard Deviation if distribution is ln Normal

Table C-2 (cont.) Descriptive Statistics and Comparison Test Results for Analysis of the 1998-99 Water Quality Parameter Dataset											
		Hardness (mg/L)		***Total-N (mg/L)***		***Dissolved-P (mg/L)***		***Total-P (mg/L)***		***Specific Conductivity (uhms/cm2)***	
Category	***Parameter***	***Cleaned***	***Uncleaned***	***Cleaned***	***Uncleaned***	***Cleaned***	***Uncleaned***	***Cleaned***	***Uncleaned***	***Cleaned***	***Uncleaned***
1998-1999 Data											
Water Quality	N of cases	28	24	27	24	21	24	27	24	21	24
	Minimum	22	22	0.5	0.5	0.09	0.07	0.1	0.1	71	50
	Maximum	160	92	2.4	2.5	0.3	0.4	0.85	0.5	386	199
	Median	62	42	1.1	0.9	0.2	0.2	0.25	0.2	130	86.5
	Mean [1]	64	49	#REF!	1.1	0.2	0.2	0.3	0.3	#REF!	100
	Standard Dev [2]	29	20	#REF!	0.5	0.1	0.1	0.1	0.1	#REF!	40
	Distribution	Normal	Neither	ln Normal	Neither	Neither	Neither	Neither	Neither	ln Normal	Neither
	Test	t-test on ranked data		t-test on ranked data		t-test on ranked data		t-test on ranked data		t-test on ranked data	
	p-value	0.04		0.82		0.60		0.74		0.00	
	p-value (Dunn-Sidak)	0.55		1.00		1.00		1.00		0.02	
	p-value (Bonferroni)	0.77		1.00		1.00		1.00		0.02	
	Significant Difference	No		No		No		No		**Yes**	

		Total Suspended Solids (mg		**Total Kjeldahl Nitrogen (mg/**		**Total Organic Carbon (mg/L**		**Total Volatile Solids (mg/L)**	
	Parameter	**Cleaned**	**Uncleaned**	**Cleaned**	**Uncleaned**	**Cleaned**	**Uncleaned**	**Cleaned**	**Uncleaned**
	N of cases	26	24	26	24	27	24	21	24
	Minimum	11	16	0.5	0.5	0.6	5.7	18	12
	Maximum	410	276	4.5	4.8	34	42	130	126
	Median	63	69	2.2	2.2	12.0	14.3	52	56
	Mean [1]	#REF!	#REF!	2.3	2.3	14.7	15.5	61	57
	Standard Dev [2]	#REF!	#REF!	0.9	1.1	7.4	8.8	29	29
	Distribution	Ln Normal	ln Normal	Normal	Normal	Normal	ln Normal	Normal	Normal
	Test	t-test on ln data		t-test on Normal data		t-test on ranked data		t-test on Normal data	
	p-value	0.67		0.94		0.99		0.64	
	p-value (Dunn-Sidak)	1.00		1.00		1.00		1.00	
	p-value (Bonferroni)	1.00		1.00		1.00		1.00	
	Significant Difference	No		No		No		No	

[1] Geometric Mean if distribution is ln Normal

[2] Geometric Standard Deviation if distribution is ln Normal

Table C-3
Descriptive Statistics and Comparison Test Results for Analysis of the 1999-00 Metals Dataset

		Cadmium (ug/L)		Chromium (ug/L)		Copper (ug/L)		Nickel (ug/L)		Lead (ug/L)		Zinc (ug/L)	
Category	**Parameter**	**Cleaned**	**Uncleaned**	**Cleaned**	**Uncleaned**	**Cleaned**	**Uncleaned**	**Cleaned**	**Uncleaned**	**Cleaned**	**Uncleaned**	**Cleaned**	**Uncleaned**
1999-2000 Data													
Total Metals	N of cases	35	33	35	33	35	33	35	33	35	33	35	33
	Minimum	0.50	0.50	2.00	3.00	13.00	4.00	2.00	2.00	11.00	9.00	57.00	74.00
	Maximum	4.50	3.70	28.00	28.00	214.00	140.00	39.00	175.00	362.00	355.00	865.00	564.00
	Median	0.90	1.10	5.00	5.00	32.00	29.00	5.00	9.00	48.00	37.00	166.00	182.00
	Mean [1]	1.14	1.05	6.70	8.42	32.43	31.62	7.46	9.44	49.65	99.67	174.03	206.37
	Standard Dev [2]	0.88	1.74	5.42	6.36	2.00	2.04	7.43	2.29	2.32	101.30	1.93	1.63
	Distribution	Neither	Ln Normal	Neither	Neither	Ln Normal	Ln Normal	Neither	Ln Normal	Ln Normal	Neither	Ln Normal	Ln Normal
	Test	t-Test on Ranked Data		t-Test on Ranked Data		t-Test on Ln Normal Data		t-Test on Ranked Data		t-Test on Ranked Data		t-Test on Ln Normal Data	
	p-value	0.27		0.16		0.88		0.00		0.83		0.23	
	p-value (Dunn-Sidak)	1.00		0.97		1.00		0.07		1.00		1.00	
	p-value (Bonferroni)	1.00		1.00		1.00		0.07		1.00		1.00	
	Significant Difference	NO		NO		NO		YES		NO		NO	
Dissolved Metals	N of cases	35	33	35	33	35	33	35	33	35	33	35	33
	Minimum	0.50	0.50	1.00	1.00	3.00	3.00	1.00	1.00	1.00	1.00	9.00	8.00
	Maximum	0.70	0.70	4.00	5.00	55.00	50.00	14.00	36.00	10.00	22.00	159.00	204.00
	Median	0.50	0.50	2.00	2.00	8.00	10.00	1.00	3.00	2.00	2.00	33.00	38.00
	Mean [1]	0.51	0.51	2.06	2.24	11.83	10.18	2.54	4.50	3.29	4.94	38.16	36.09
	Standard Dev [2]	0.04	0.03	0.78	0.93	10.35	1.91	2.72	6.63	2.62	5.86	1.97	1.88
	Distribution	Neither	Neither	Neither	Neither	Neither	Ln Normal	Neither	Neither	Neither	Neither	Ln Normal	Ln Normal
	Test	t-Test on Ranked Data		t-Test on Ranked Data		t-Test on Ranked Data		t-Test on Ranked Data		t-Test on Ranked Data		t-Test on Ln Normal Data	
	p-value	0.60		0.53		0.42		0.03		0.75		0.73	
	p-value (Dunn-Sidak)	1.00		1.00		1.00		0.50		1.00		1.00	
	p-value (Bonferroni)	1.00		1.00		1.00		0.68		1.00		1.00	
	Significant Difference	NO		NO		NO		NO		NO		NO	

Notes:

[1] Geometric Mean if distribution is Ln Normal, Arithmetic Mean if distribution is Normal or not Normal (Niether)

[2] Geometric Standard Deviation if distribution is Ln Normal

Table C-3 (cont.)
Descriptive Statistics and Comparison Test Results for Analysis of the 1999-00 Water Quality Parameter Dataset

Category	Parameter	Hardness (mg/L)		Total-N (mg/L)		Dissolved-P (mg/L)		Total-P (mg/L)		Specific Conductivity (uhms/cm2)	
		Cleaned	Uncleaned	Cleaned	Uncleaned	Cleaned	Uncleaned	Cleaned	Uncleaned	Cleaned	Uncleaned
1999-2000 Data											
Water Quality	N of cases	35	33	31	29	35	33	35	33	35	34
	Minimum	15.00	26.00	0.19	0.32	0.10	0.10	0.10	0.10	32.00	59.00
	Maximum	119.00	448.00	4.00	2.70	0.81	0.74	0.92	0.82	273.00	923.00
	Median	34.00	52.00	0.60	1.00	0.16	0.19	0.26	0.33	77.00	142.00
	Mean [1]	34.94	58.67	0.68	0.94	0.17	0.22	0.24	0.32	78.36	145.40
	Standard Dev [2]	1.64	1.88	1.94	1.81	1.67	1.68	1.77	1.74	1.67	1.85
	Distribution	Ln Normal	Ln Normal	Ln Normal	Normal	Ln Normal	Ln Normal	Normal	Normal	Ln Normal	Ln Normal
	Test	t-Test on Ln Normal Data		t-Test on Ln Normal Data		t-Test on Ln Normal Data		t-Test on Normal Data		t-Test on Ln Normal Data	
	p-value	0.00		0.05		0.03		0.06		0.00	
	p-value (Dunn-Sidak)	0.01		0.66		0.47		0.74		0.00	
	p-value (Bonferroni)	0.01		1.00		0.62		1.00		0.00	
	Significant Difference	YES		NO		NO		NO		YES	

	Parameter	Total Suspended Solids (mg/L)		Total Kjeldahl Nitrogen (mg/L)		Total Organic Carbon (mg/L)		Total Volatile Solids (mg/L)	
		Cleaned	Uncleaned	Cleaned	Uncleaned	Cleaned	Uncleaned	Cleaned	Uncleaned
	N of cases	35	33	35	33	35	33	35	33
	Minimum	10.00	14.00	0.60	0.80	3.00	4.80	1.00	1.00
	Maximum	606.00	527.00	7.00	6.20	51.00	48.50	152.00	128.00
	Median	70.00	93.00	1.40	2.00	9.70	14.60	20.00	48.00
	Mean [1]	72.19	95.50	1.53	1.89	9.77	13.85	30.43	49.00
	Standard Dev [2]	2.53	2.48	1.73	1.54	1.99	1.67	29.10	27.89
	Distribution	Ln Normal	Ln Normal	Ln Normal	Ln Normal	Ln Normal	Ln Normal	Neither	Neither
	Test	t-Test on Ln Normal Data		t-Test on Ln Normal Data		t-Test on Ln Normal Data		t-Test on Ranked Data	
	p-value	0.21		0.08		0.02		0.00	
	p-value (Dunn-Sidak)	0.99		0.82		0.35		0.02	
	p-value (Bonferroni)	1.00		1.00		0.42		0.02	
	Significant Difference	NO		NO		NO		YES	

[1] Geometric Mean if distribution is Ln Normal, Arithmetic Mean if distribution is Normal or not Normal (Niether)

[2] Geometric Standard Deviation if distribution is Ln Normal

Table C-4

Descriptive Statistics and Comparison Test Results for Analysis of the 2000-2001 Metals Dataset

Category	Parameter	Cadmium (ug/L)		Chromium (ug/L)		Copper (ug/L)		Nickel (ug/L)		Lead (ug/L)		Zinc (ug/L)	
		Cleaned	**Uncleaned**	**Cleaned**	**Uncleaned**	**Cleaned**	**Uncleaned**	**Cleaned**	**Uncleaned**	**Cleaned**	**Uncleaned**	**Cleaned**	**Uncleaned**
2000-2001 Data													
Total Metals	N of cases	14	16	14	16	14	16	14	16	14	16	14	16
	Minimum	0.23	0.25	3.30	2.99	12.40	12.30	2.88	2.17	4.88	6.59	71.60	49.80
	Maximum	1.45	0.83	8.64	9.13	59.50	65.00	23.70	7.80	113.00	57.90	381.00	230.00
	Median	0.65	0.54	5.80	5.43	23.25	26.45	5.84	5.38	12.50	19.00	151.50	126.50
	Mean [1]	0.67	0.51	5.72	5.59	24.04	24.05	6.69	4.63	14.89	18.98	161.33	123.58
	Standard Dev [2]	1.55	1.46	1.34	1.38	1.57	1.55	1.81	1.49	2.45	1.88	86.03	1.45
	Distribution	Ln Normal	Normal	Normal	Normal	Ln Normal	Normal	Normal	Normal	Ln Normal	Ln Normal	Neither	Normal
	Test	t-Test on Ln Normal Data		t-Test on Normal Data		t-Test on Ln Normal Data		t-Test on Normal Data		t-Test on Ln Normal Data		t-Test on Ranked Data	
	p-value	0.08		0.90		1.00		0.07		0.41		0.40	
	p-value (Dunn-Sidak)	0.81		1.00		1.00		0.77		1.00		1.00	
	p-value (Bonferroni)	1.00		1.00		1.00		1.00		1.00		1.00	
	Significant Difference	NO		NO		NO		NO		NO		NO	
Dissolved Metals	N of cases	14	16	14	16	14	16	14	16	14	16	14	16
	Minimum	0.20	0.20	1.00	1.00	5.55	5.40	2.00	2.00	1.00	1.00	27.90	25.30
	Maximum	0.67	0.51	2.64	3.64	35.00	34.60	6.23	4.50	6.40	29.60	114.00	155.00
	Median	0.21	0.20	1.66	1.84	11.30	12.95	2.75	2.10	1.00	2.05	59.70	49.30
	Mean [1]	0.29	0.26	1.67	2.21	11.75	12.45	3.05	2.57	2.12	2.90	58.18	54.78
	Standard Dev [2]	0.14	0.10	1.28	0.77	1.66	1.63	1.49	0.78	1.78	2.80	1.58	1.63
	Distribution	Neither	Neither	Normal	Neither	Normal	Ln Normal	Ln Normal	Neither	Neither	Ln Normal	Normal	Ln Normal
	Test	t-Test on Ranked Data		t-Test on Ranked Data		t-Test on Ln Normal Data		t-Test on Ranked Data		t-Test on Ranked Data		t-Test on Ln Normal Data	
	p-value	0.41		0.08		0.75		0.15		0.03		0.73	
	p-value (Dunn-Sidak)	1.00		0.81		1.00		0.97		0.50		1.00	
	p-value (Bonferroni)	1.00		1.00		1.00		1.00		0.67		1.00	
	Significant Difference	NO		NO		NO		NO		NO		NO	

Notes:

[1] Geometric Mean if distribution is Ln Normal, Arithmetic Mean if distribution is Normal or not Normal (Niether)

[2] Geometric Standard Deviation if distribution is Ln Normal

Table C-4_cont

Descriptive Statistics and Comparison Test Results for Analysis of the 2000-2001 Water Quality Parameter Datase

Category	Parameter	Hardness (mg/L)		Total-N (mg/L)		Dissolved-P (mg/L)		Total-P (mg/L)		Specific Conductivity (uhms/cm2)	
		Cleaned	Uncleaned	Cleaned	Uncleaned	Cleaned	Uncleaned	Cleaned	Uncleaned	Cleaned	Uncleaned
2000-2001 Data											
Water Quality	N of cases	14	16	14	16	10	13	14	16	14	16
	Minimum	12.00	12.00	0.40	0.61	0.03	0.05	0.14	0.12	18.00	40.00
	Maximum	142.00	168.00	4.20	3.30	0.35	0.37	0.43	0.68	252.00	266.00
	Median	47.00	41.00	1.12	1.31	0.15	0.14	0.21	0.23	74.50	77.50
	Mean [1]	44.27	44.42	1.32	1.48	0.14	0.15	0.23	0.25	73.49	87.71
	Standard Dev [2]	2.04	1.97	2.08	1.55	2.17	1.88	1.51	1.70	2.33	1.60
	Distribution	Normal	Ln Normal	Ln Normal	Ln Normal	Normal	Normal	Ln Normal	Normal	Ln Normal	Ln Normal
	Test	t-Test on Ln Normal Data		t-Test on Ln Normal Data		t-Test on Ln Normal Data		t-Test on Ln Normal Data		t-Test on Ln Normal Data	
	p-value	0.99		0.62		0.96		0.54		0.50	
	p-value (Dunn-Sidak)	1.00		1.00		1.00		1.00		1.00	
	p-value (Bonferroni)	1.00		1.00		1.00		1.00		1.00	
	Significant Difference	NO		NO		NO		NO		NO	

Parameter	Total Suspended Solids (mg/L)		Total Kjeldahl Nitrogen (mg/L)		Total Organic Carbon (mg/L)		Total Volatile Solids (mg/L)	
	Cleaned	Uncleaned	Cleaned	Uncleaned	Cleaned	Uncleaned	Cleaned	Uncleaned
N of cases	14	16	14	16	14	16	14	16
Minimum	20.00	9.00	0.10	0.10	1.60	2.90	16.00	6.00
Maximum	92.00	80.00	2.90	2.10	19.80	22.50	274.00	52.00
Median	52.00	40.50	0.70	0.55	7.40	8.15	44.00	36.00
Mean [1]	48.03	35.41	0.67	0.56	7.22	7.77	47.66	29.16
Standard Dev [2]	1.63	2.02	2.59	2.29	1.95	1.69	2.29	1.83
Distribution	Normal	Normal	Ln Normal	Ln Normal	Normal	Ln Normal	Ln Normal	Normal
Test	t-Test on Normal Data		t-Test on Ln Normal Data		t-Test on Ln Normal Data		t-Test on Ln Normal Data	
p-value	0.25		0.61		0.74		0.08	
p-value (Dunn-Sidak)	1.00		1.00		1.00		0.83	
p-value (Bonferroni)	1.00		1.00		1.00		1.00	
Significant Difference	NO		NO		NO		NO	

Notes:

[1] Geometric Mean if distribution is Ln Normal, Arithmetic Mean if distribution is Normal or not Normal (Niether)

[2] Geometric Standard Deviation if distribution is Ln Normal